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First Powerhouse, Bonneville Dam, Columbia River, Oregon
Report 1, Proposed Trash Holding System

Hydraulic Model Investigation

Robert Davidson

April 2000

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Report 1, Proposed Trash Holding System

Hydraulic Model Investigation

by Robert Davidson

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Preface

Experiments to evaluate potential trash boom designs for the First Powerhouse at Bonneville Dam, Columbia River, Portland, OR, were performed for U.S. Army Engineer District, Portland (NPD). Initial funding for this study was received by U.S. Army Engineer Research and Development Center on 6 January 1999.

This study was conducted in the Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, ERDC, during January 1999 to June 1999 under the direction of Dr. J. R. Houston, Director, CHL, and Dr. P.G. Combs, Chief, Rivers and Structures Division, CHL.

Model velocity information was obtained and plotted by Mr. Marshall Thomas and Mrs. Danea Polk, hydraulic technicians, under the direct supervision of Mr. Robert A. Davidson, research hydraulic engineer. Analysis of the velocity information and final presentation of the information was accomplished by Mr. Davidson under the supervision of Mr. J. F. George, Chief, Fisheries and Structural Hydrodynamic Branch. This report was written by Mr. Davidson.

During the course of the model study, Dr. Stephen Schlenker, hydraulic engineer, Portland District, and Mr. Wally Bennett (architectural/engineering firm designer, CH2M Hill Companies, Ltd.) visited ERDC to observe model operation, review experiment results, and participate in experiment planning.

At the time of publication of this report, Dr. Lewis E. Link was Acting Director of ERDC, and COL Robin R. Cababa, EN, was Commander.

1 Introduction

Background

Bonneville Dam is located on the Columbia River at river mile 146.1, approximately 64.37388 km (40 miles) east of Portland, OR (Figure 1). It is a multipurpose project consisting of the first and second powerhouses, the old and new navigation locks, and a 45,308.8-cu m/sec (1,600,000-cfs) capacity spillway. Construction of the first powerhouse, the old navigation lock, and spillway began in 1933. President Franklin D. Roosevelt dedicated the lock and dam on September 28, 1937. The construction of the first powerhouse was completed in 1943. The first powerhouse has a flow capacity of approximately 3,624.7040 cu m/sec (128,000 cfs) and a rated power output of 526,700 kW. Construction of the second powerhouse began in 1974 and was completed in 1981. It has a flow capacity of approximately 4,530.88 cu m/sec (160,000 cfs) and a rated power output of 558,200 kW.

Purpose

Potential changes to the juvenile bypass system for Bonneville First Powerhouse would significantly reduce the flow capacity of the existing ice and trash sluiceway. As a result, the sluiceway would not be able to pass trash and ice from the forebay to the tailrace efficiently. The existing 1:40-scale model of the Bonneville First Powerhouse was used to evaluate possible trash boom location scenarios that could be used to collect and direct ice and trash to the Unit 0 (Figure 2) sluiceway opening efficiently. Velocities were obtained along the trash boom to determine the hydraulic loading. Several different debris types were used to evaluate the effectiveness of various trash boom designs.

Figure 1. Project location

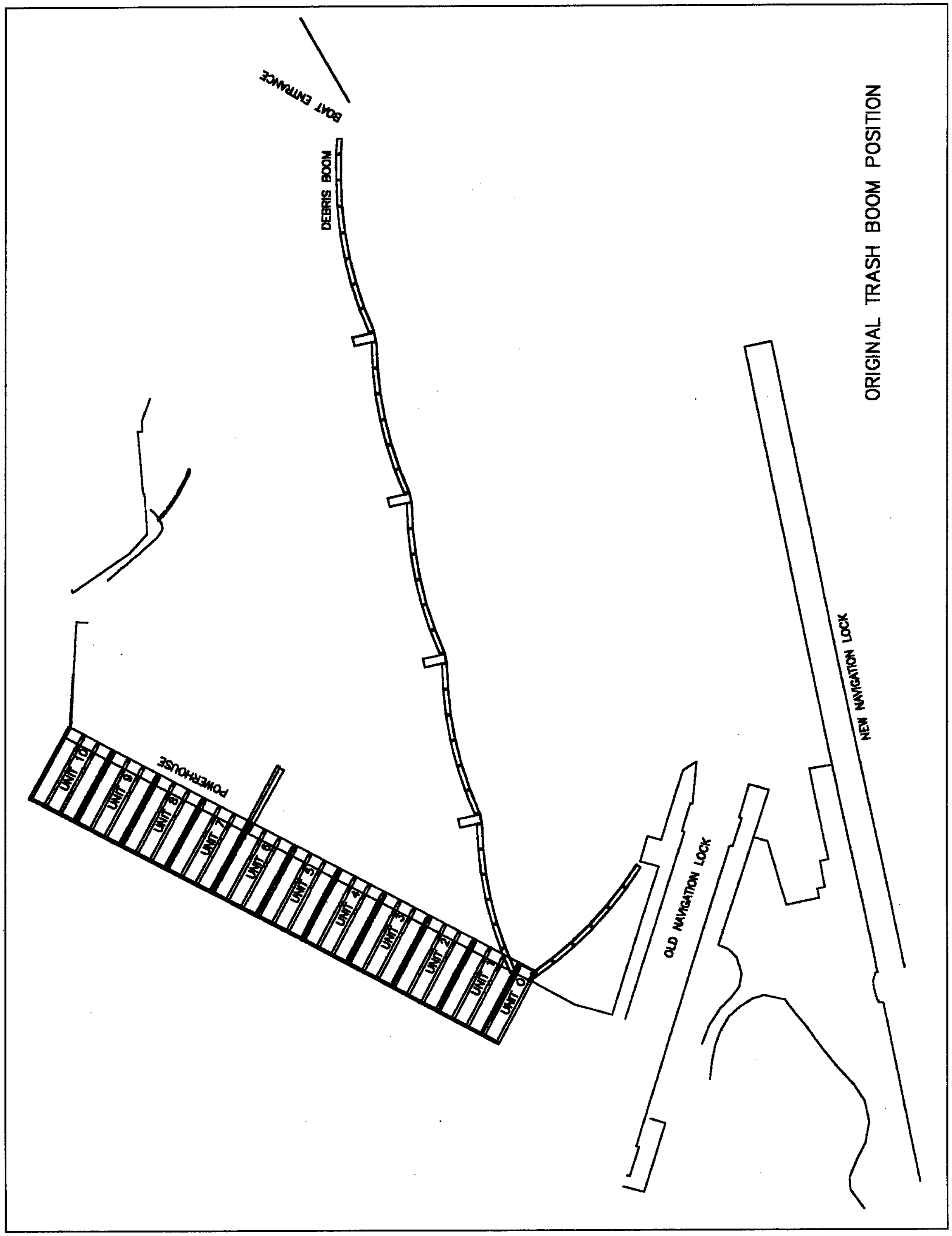


Figure 2. Unit 0 location

2 Scale Model

Similitude

Complete similitude in a laboratory model is attained when geometric, kinematic, and dynamic similitude is satisfied. Physical models of hydraulic structures with both internal flow (pressure flow) and external flow (free surface) typically are scaled using kinematic (Froudian) similitude at a large enough scale so that the viscous effects in the scaled model can be neglected. Velocities scaled using kinematic similitude (model Froude number equal to prototype Froude number) in a 1:40-scale model have maximum Reynolds numbers at the peak discharge on the order of 10^5, yet the corresponding prototype values are on the order of 10^7.

Because the friction factor decreases with increasing Reynolds number, the model is hydraulically too rough. The scaled friction losses in the model will be larger than those experienced by the prototype structure. However, the focus of this study is the determination of flow lines in the approach channel and the movement of various types of debris in this vicinity. Since only a portion of the powerhouse structure was reproduced, the difference in the model-to-prototype friction losses would not be significant. Also, the difference in roughness of the topography between the prototype and the model would be difficult to determine since prototype information on the approach channel is not available. It is very important that the model accurately reproduces enough of the approach topography and specific portions of the intake of the powerhouse to develop flow conditions properly. The upstream limit of the model was established based on the prototype channel so the entering flow within the boundaries would be fully developed in the area of consideration. Since the model topography exceeds twenty times the depth upstream from the area being investigated, the velocity measurements in this scale model should compare favorably with those present in the prototype resulting in correct and proper debris movement in this area.

Interpretation of Experimental Results

The accepted equations of hydraulic similitude, based on the Froudian relations, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. General relations for the transfer of model data to prototype equivalents, or vice versa, are presented in the following tabulation:

Dimension	Ratio	Scale Relations Model:Prototype
Length	$L_r=L$	1:40
Area	$A_r=L_r^2$	1:1600
Velocity	$V_r=L_r^{1/2}$	1:6.32
Time	$T_r=L_r^{1/2}$	1:6.32
Discharge	$Q_r=L_r^{5/2}$	1:10,119

Model Description

A 1:40-scale model of the Bonneville First Powerhouse was constructed in 1995 (Figure 3). All 10 powerhouse units were reproduced from acrylic, including the ice and trash sluiceway and the juvenile bypass channel. Approximately 487.68 m (1,600 ft) of approach topography was also reproduced. The U.S. Army Engineer District, Portland, supplied topographical plots, which were transferred into an electronic format. This information was then used to produce templates, which were set to grade in the approach steel flume that had been fabricated for this model. Concrete was poured and smoothed between the templates. The upstream portions of the new and old navigation locks were reproduced from plastic-coated plywood. In addition, submerged traveling screens and vertical barrier screens were reproduced from brass and installed in the model.

Original Trash Boom Components Description

A 411.48-m- (1,350-ft-) long trash boom consisting of five sections, was constructed of Plexiglas at a model scale of 1:40. Each section consisted of six 12.192-m- (40-ft-) long boom pieces (Figure 4) and was separated by and attached to an anchor float (Figures 5 and 6). Each trash boom and anchor section had a depth of 1.0668 m (3.5 ft) and had a 2.1336-m- (7-ft-high) fence attached to the upstream surface. These sections were weighted so when they were placed in the water there would be 1.2192 m (4 ft) of fence below the water surface and 0.9144 m (3 ft) of fence above the water surface. This trash boom assembly was placed in the model (Figures 7 and 8), extending from Unit 0 to the north shore at a 50-degree angle with respect to the powerhouse. The trash boom was held in place at each anchor float by braided fishing line, which was attached to the invert of the channel and both sides of the anchor float. The trash boom was also attached by eyehooks to the powerhouse face at the downstream end and to a pipe that was driven into the topography at the upstream end. At

Figure 3. General view of model looking downstream

the upstream end of the trash boom assembly, three pipes were driven into the topography. Two pipes supported the upstream end of the trash boom. The other pipe supported a vertical wall between the pipe and the north shore. This pipe and wall arrangement formed a boat entrance (Figure 9) that would be important to allow passage of boats around the trash boom to access the dam. In addition to the 411.48-m- (1,350-ft-) long trash boom a 73.152-m- (240 ft-) long trash boom (entrance boom) was fabricated and installed between unit 0 and the outside of the old navigation lock.

The entrance to the ice and trash sluiceway, at Unit 0, was modified so that the width of the opening was 6.096 m (20-ft) and the invert was elevation (el) 68.0 ft.[1] The area downstream of the entrance was modified to more closely represent what would be expected at the project. The original model was not designed to investigate this area of the project. This modification was performed to evaluate the effectiveness of the Unit 0 configuration to pass debris into the ice and trash sluiceway.

[1] All elevations (el) cited herein are in feet referenced to the National Geodetic Vertical Datum (NGVD) (to convert feet to meters, multiply number of feet by 0.3048).

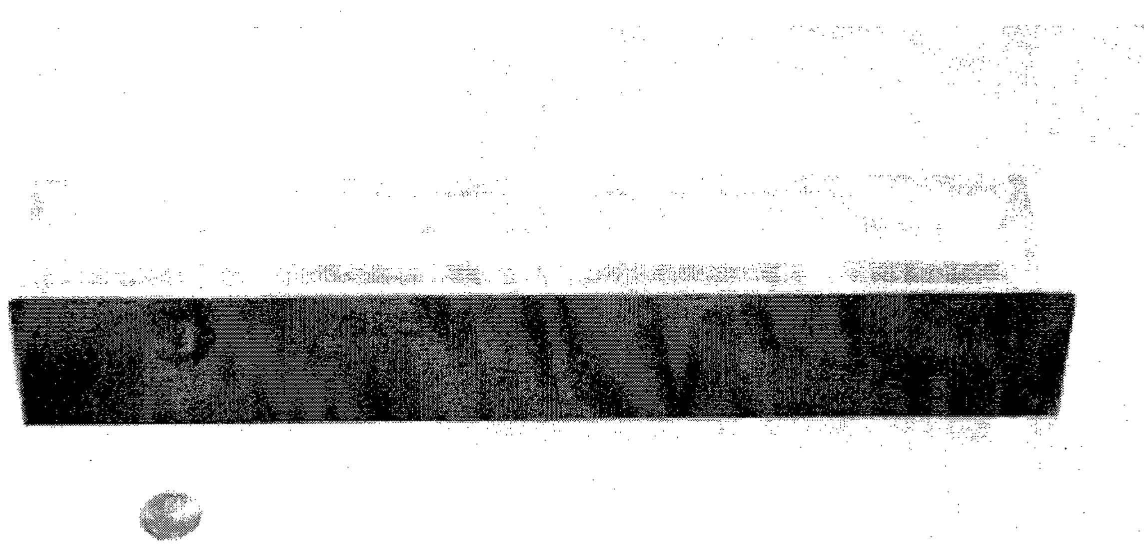


Figure 4. Trash boom piece

Model Debris

Debris used during this study consisted of wet and dry branchy cedar, pine needles, dry and wet wooden dowels corresponding to a 0.3048-m- (1-ft-) diameter tree in lengths of 3.810 - 18.288 m (12.5 - 60 ft), plastic that simulated ice, and the root systems of sapling cedar trees (Figures 10 - 12). All debris was cut to sizes that would be expected at the prototype structure. During later experiments wooden dowels simulating 1.0668-m- (3.5-ft-) diameter debris were also used.

Calibration of Model

Water was supplied to the model by six pumps, each pump capable of supplying 0.0850 cu m/sec (3 cfs) (model). This provides a total inflow capacity of approximately 5,153.876 cu m/sec (182,000 cfs) (prototype). A data industrial flow meter was placed in each inflow supply line. Each flow meter was calibrated in the Coastal and Hydraulic Laboratory Volumetric Calibration Flume prior to installation.

Each powerhouse unit was constructed with three vertical control gates located at the center line of the turbine. Each of the three gates is operated

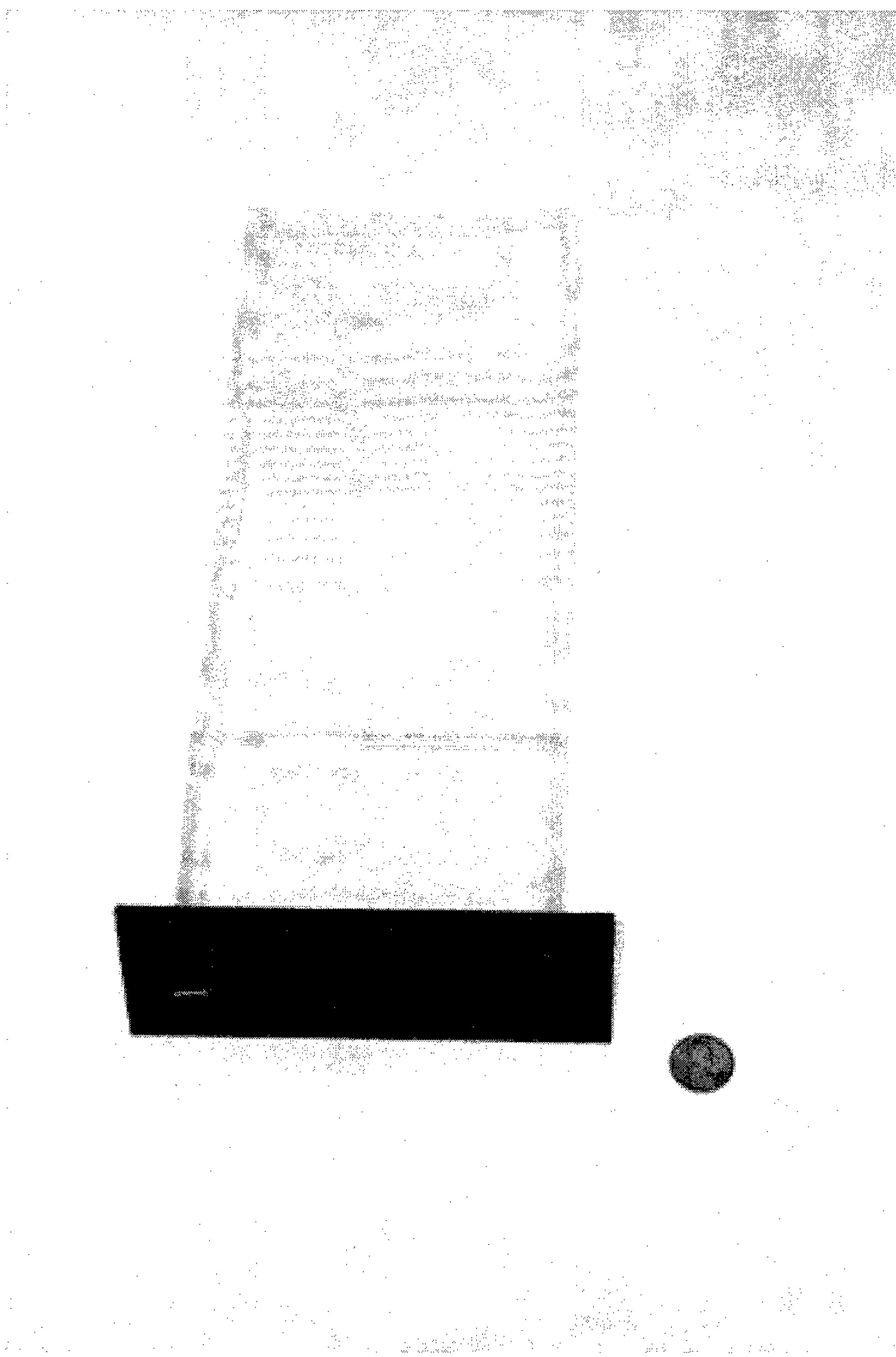


Figure 5. Anchor float

separately, and controls flow though an individual bay of the powerhouse unit. Based on information obtained from the 1:25-scale Bonneville First Powerhouse section model, the flow through each bay of the powerhouse unit is nearly equal.

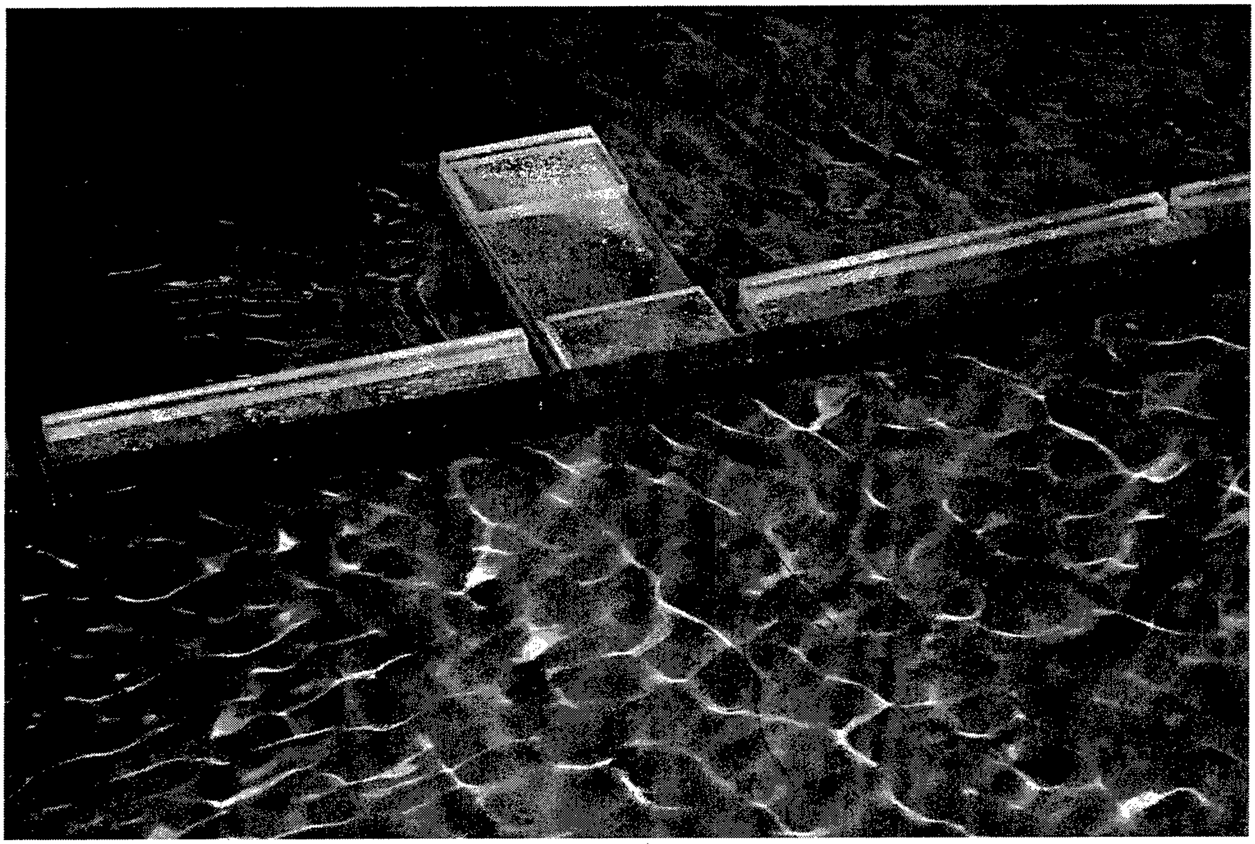


Figure 6. Assembled anchor float and boom pieces

The control gates in the powerhouse were calibrated by setting all of its gates to a certain opening. A specific discharge was input into the model and the upper pool was allowed to reach equilibrium. This head pool was recorded and additional water was input into the model. This procedure was repeated until the upper pool elevation exceeded el 80. This entire procedure was repeated until the flow through each unit exceeded 369.452 cu m/sec (14,000 cfs) (prototype value).

Velocity information was obtained in the model with an Acoustic Doppler Velocity Meter (ADV). Calibration of this instrument was performed by the manufactor. Its accuracy is 0.25 percent, which would yield an accuracy of ±0.003 m/sec (0.01 ft/sec) (prototype) in the velocity ranges for these experiments.

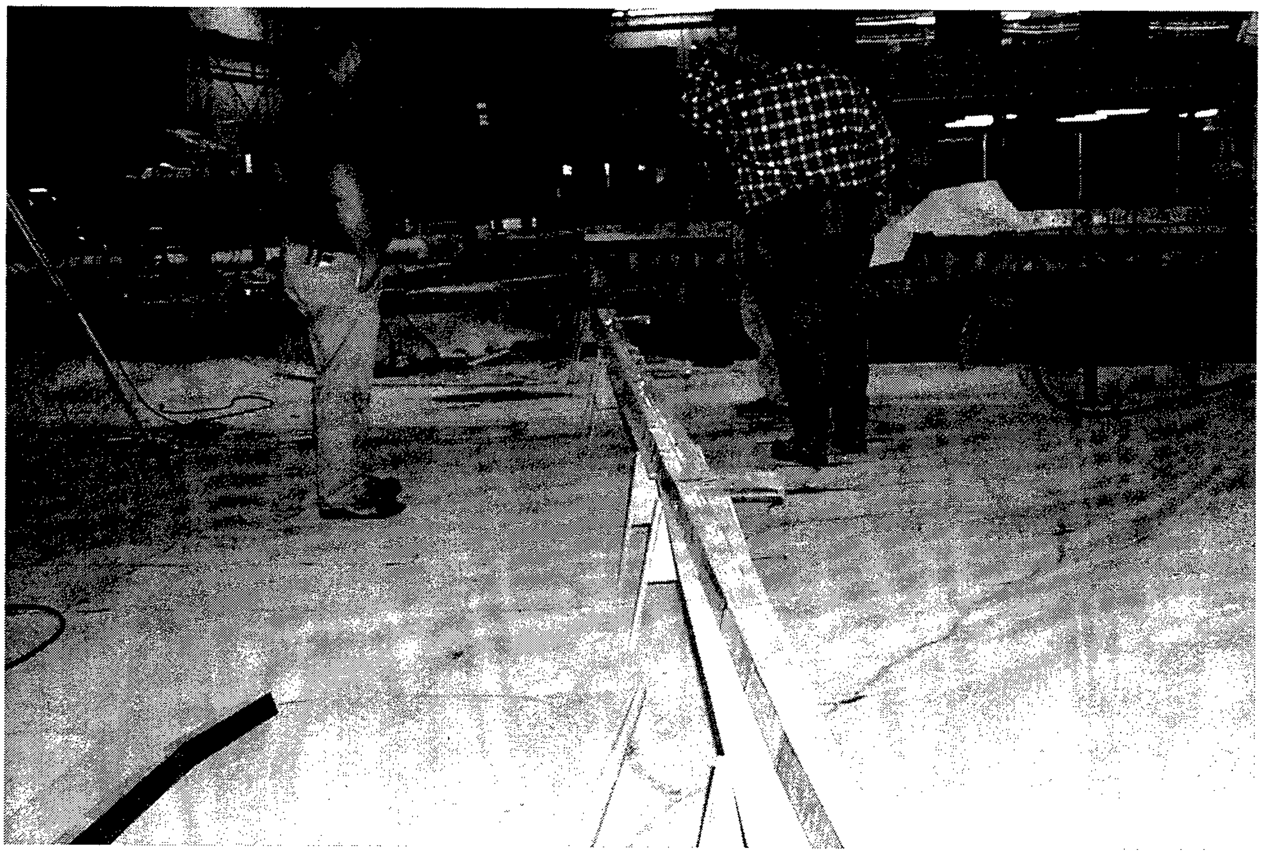


Figure 7. Trash boom assembly in the process of being installed

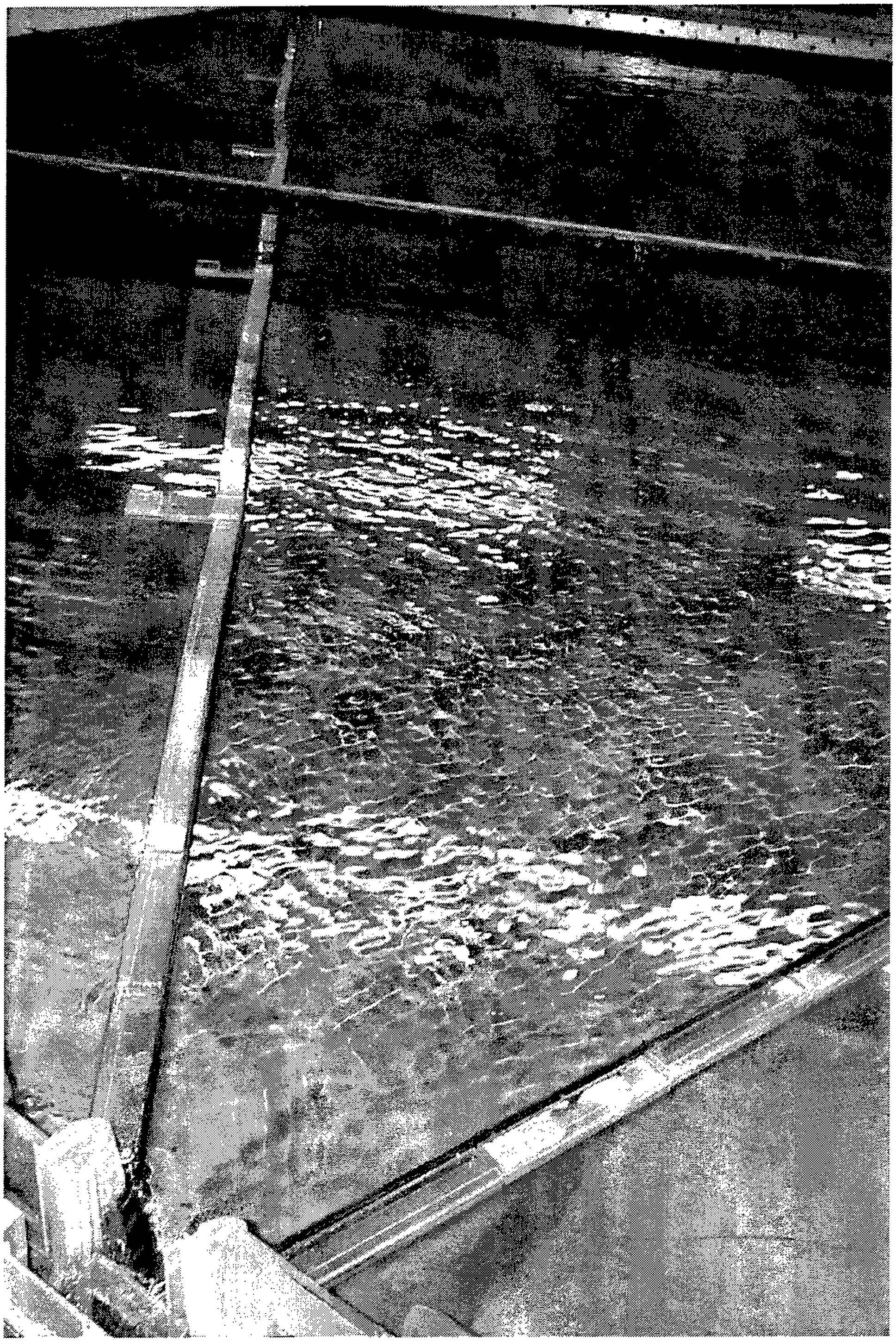


Figure 8. Original trash boom assembly installed in model

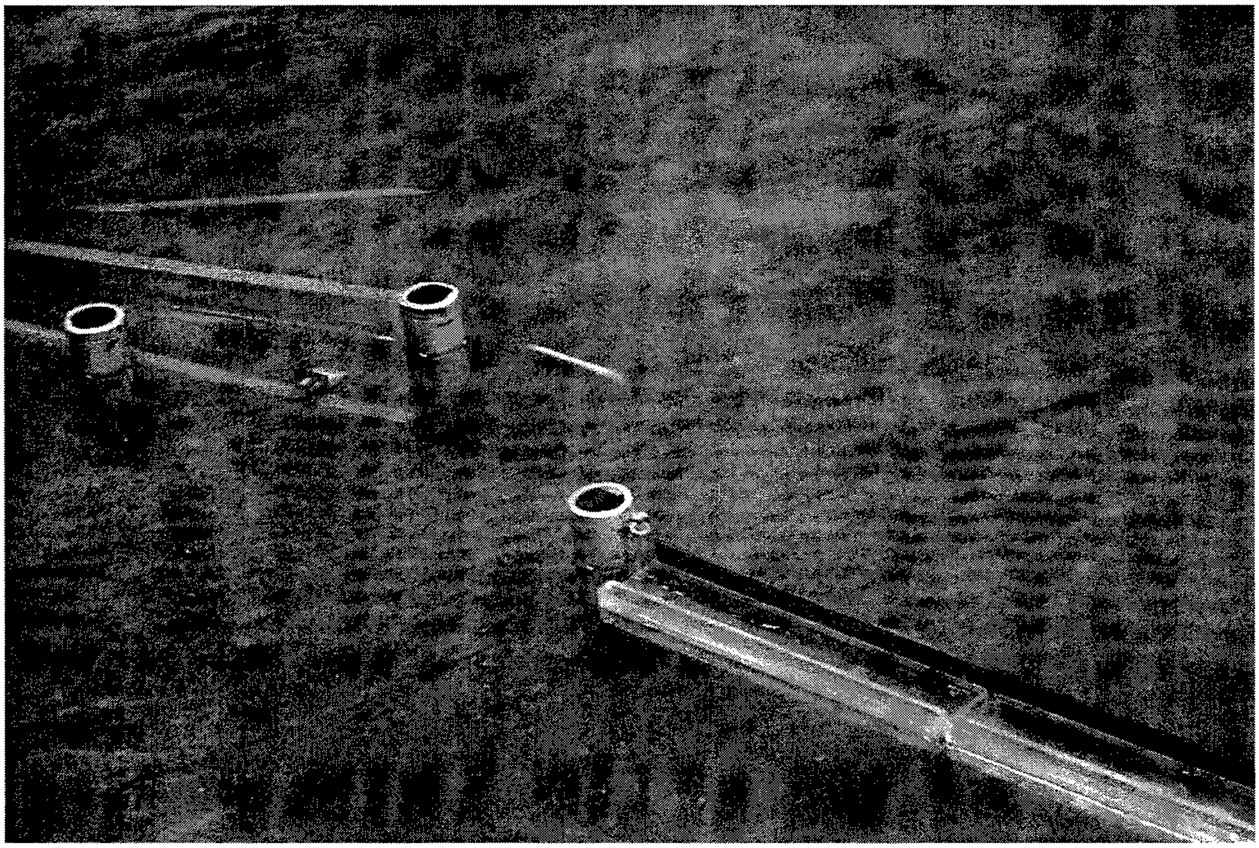


Figure 9. Original trash boom boat entrance

Figure 10. Wet cedar, pine debris, and dowel debris

Figure 11. Dried cedar and pine debris

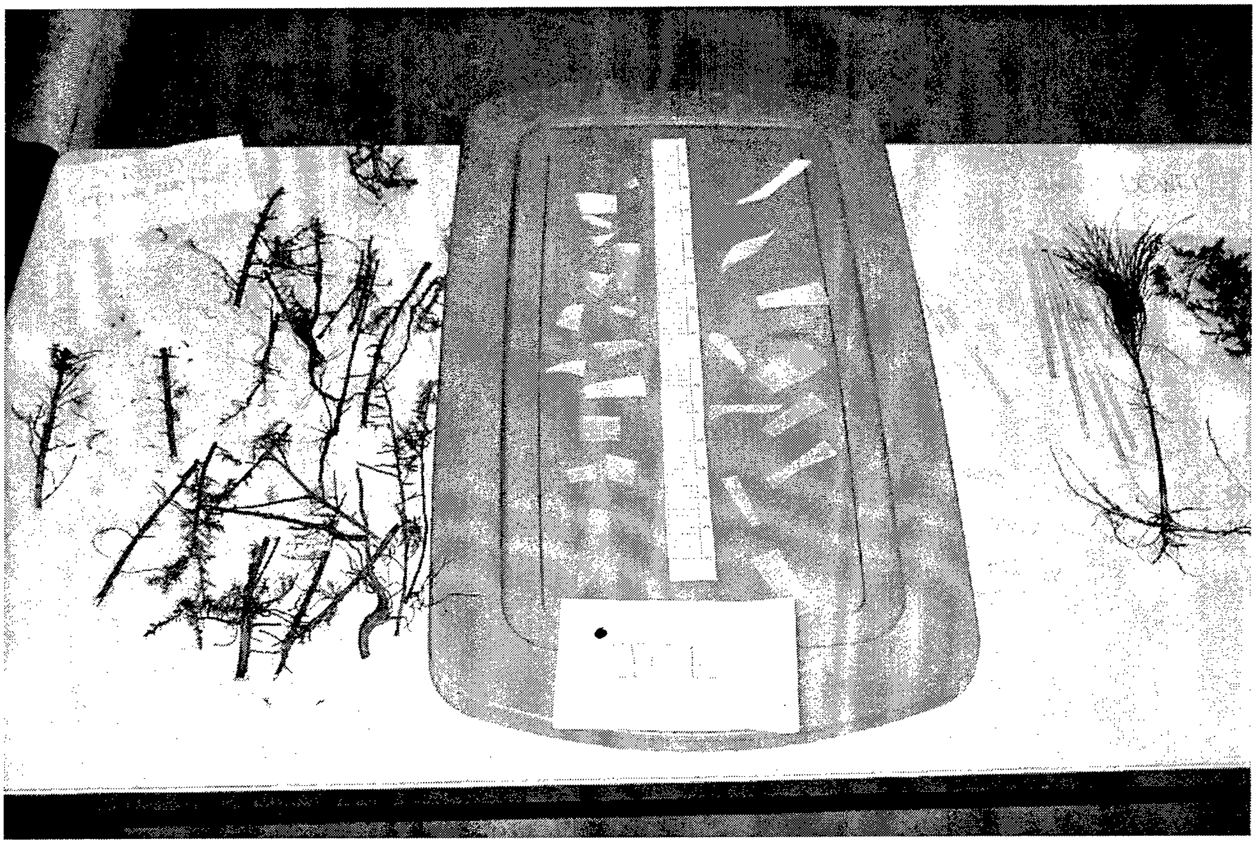


Figure 12. Simulated ice and various debris

3 Model Experiments and Results

Experimental Conditions

The scope of work sent to the Coastal and Hydraulics Laboratory by the Portland District requested debris experiments to be performed on a trash boom configuration. The configuration chosen by the Portland District, described previously, was known as Alternative 3 in the Bonneville First Alternative Study.[1] These experiments were to be conducted for two different powerhouse operations (unit discharges of 297.339 cu m/sec (10,500 cfs) and 382.293 cu m/sec (13,500 cfs)) and for three different pool elevations (el 77, 74.5, and 71.5). In addition, a total of 100 velocity measurements were to be obtained along the trash boom, in the vicinity of the boat entrance, and near the entrance to Unit 0.

Alternative 3 Boom Alignment (Original) Experiments

Unit discharge = 297.339 cu m/sec (10,500 cfs); pool el = 77.0

Each of the 10 powerhouse units was set with a discharge of 297.339 cu m/sec (10,500 cfs) for an upper pool el 77.0. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels had lengths ranging from 18.288 m (60 ft) (prototype) to a minimum length of 1.8288 m (6 ft). These dowels were introduced as a group and separately. All dowels moved along the trash boom to the entrance to Unit 0. None of the 18.288-m (60-ft) dowels passed into the ice and trash sluiceway (Photo 1). Some of the 12.192-m (40-ft) dowels hung up in the ice and trash sluiceway and caused the smaller dowels to become lodged

[1] Forebay Trash Handling System prepared for the Portland District by CH2M Hill, July 1998.

around them. However, without the 12.192-m (40-ft) and 18.288-m (60-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. The 12.192-m (40-ft) dowels became lodged because of structural features of the ice and trash sluiceway.

Debris experiments were repeated with a mixture of 10.0584 (33-), 8.2296- (27-), 6.096- (20-), and 3.9624-m (13-ft-) long dowels in combination with wet cedar, dry cedar, and root balls. Most of the debris traveled down the trash boom (Photo 2) to the entrance to the ice and trash sluiceway at Unit 0. However, some of the larger pieces of cedar and root balls became entangled on the boom support strings and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom (Photo 3) at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse was pulled mainly to Units 1-2 and piled up against the backside of the boom and the face of the powerhouse (Photo 4). Some of the 10.0584-m (33-ft) dowels were caught at the entrance to the ice and trash sluiceway, at Unit 0, by turning sideways between the two trash booms, blocking other debris from passing freely. When this did not happen, all debris passed freely into and through the ice and trash sluiceway.

Unit discharge = 297.339 cu m/sec (10,500 cfs); pool el = 74.5

Each of the 10 powerhouse units was set with a discharge of 297.339 cu m/sec (10,500 cfs) for an upper pool elevation of 74.5. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels, which were added individually and all together had lengths ranging from 60 ft (prototype length) to a minimum length of 1.8288 m (6 ft). All dowels moved along the trash boom to the entrance to Unit 0. None of the 18.288-m (60-ft) (Photo 5) or 12.192-m (40-ft) dowels passed into the ice and trash sluiceway. Some of the 10.0584-m (33-ft) dowels were caught in the ice and trash sluiceway and caused the smaller dowels to become lodged around them. However, without the 10.0584-m (33-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. Also a few of the 8.2296-m (27-ft) dowels hung between the two trash booms in the Unit 0 ice entrance when placed in the model by themselves.

Debris experiments were repeated with a mixture of 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar, and root balls (Photo 6). Most of the debris traveled down the trash boom to the entrance, then to the ice and trash sluiceway at Unit 0. However, some of the larger pieces of cedar and root balls became entangled on the boom support strings (Photo 7), and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse was pulled mainly to Units 1-2 and piled up against the backside of the boom. Some of the 8.2296-m (27-ft) dowels hung up at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0 blocking other debris from passing freely. If this did not happen, all debris that made it to Unit 0 passed freely into and through the ice and trash sluiceway.

Velocities were measured so that the potential loading on the trash boom could be calculated. Velocities measured along the trash boom for this condition can be seen in Plates 1-3. These velocities were obtained near the surface and at depths of 1.5240 and 3.048 m (5 and 10 ft). Velocities obtained in the boat entrance can be seen in Plates 4-9. These velocities, debris experiments (Photo 8), and dye experiments (Photo 9) indicate that debris should not enter and that boats should be able to navigate into the opening.

Unit discharge = 297.339 cu m/sec (10,500 cfs); pool el = 71.5

Each of the 10 powerhouse units was set with a discharge of 297.339 cu m/sec (10,500 cfs) and the upper pool elevation was set at el 71.5. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels, which were introduced together and separately, had lengths ranging from 18.288 m (60 ft) (prototype) to a minimum length of 1.8288 m (6 ft). All dowels moved along the trash boom (Photo 10) to the entrance of Unit 0. None of the 18.288-m (60-ft) or 12.192-m (40-ft) (Photo 11) dowels passed into the ice and trash sluiceway. Some of the 10.0584-m (33-ft) dowels hung up in the ice and trash sluiceway and caused the smaller dowels to become lodged around them. However, without the 10.0584-m (33-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. Also a few of the 8.2296-m (27-ft) dowels hung between the two trash booms in the Unit 0 ice entrance when placed in the model by themselves.

Debris experiments were repeated with a mixture of 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar and root balls. Most of the debris traveled down the trash to the entrance to the ice and trash sluiceway at Unit 0. However, some of the larger pieces of cedar and root balls became entangled on the boom support strings and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse (Photo 12) was pulled mainly to Units 1-2 and piled up against the backside of the boom. Some of the 8.2296-m (27-ft) dowels hung up at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0, blocking other debris from passing freely. If this did not happen, all debris that made it to Unit 0, passed freely into and through the ice and trash sluiceway (Photo 13).

Unit discharge = 382.293 cu m/sec (13,500 cfs); pool el = 77.0

Each of the 10 powerhouse units was set with a discharge of 382.293 cu m/sec (13,500 cfs) for an upper pool elevation of 77.0. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels, which were introduced together together and separately, had lengths ranging from 18.288 m (60 ft) (prototype length) to a minimum length of 1.8288 m (6 ft). All dowels moved along the trash boom to the entrance to Unit 0. None of the 18.288-m (60-ft) dowels passed into the ice and trash sluiceway (Photo 14). Some of the 12.192-m (40-ft) and 10.0584-m (33-ft) dowels hung up in the ice and trash sluiceway and caused the smaller dowels to become lodged around them. However, without the 18.288-m (60-ft) and 12.192-m (40-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. Also a few of the 8.2296-m (27-ft) and 10.0584-m (33-ft) dowels hung between the two trash booms in the Unit 0 ice entrance (Photo 15), when placed in the model by themselves.

Debris experiments were repeated with a mixture of 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar, and root balls. Most of the debris traveled down the trash to the entrance to the ice and trash sluiceway at Unit 0. However, some of the larger pieces of cedar and root balls became entangled on the boom support strings (Photo 16) and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse was pulled mainly to Units 1-2 and piled up against the backside of the boom (Photo 17). Some of the 8.2296-m (27-ft) dowels hung up at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0, blocking other debris from passing freely. After a period of time the trash built up behind the log and finally washed the longer log through to the ice and trash sluiceway. If the 8.2296-m (27-ft) log passed through to the ice and trash sluiceway, then all debris that made it to Unit 0 also passed freely through.

Unit discharge = 382.293 cu m/sec (13,500 cfs); pool el = 74.5

Each of the 10 powerhouse units was set with a discharge of 382.293 cu m/sec (13,500 cfs) and the upper pool elevation was set at el 74.5. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels, which were introduced together and separately, had lengths ranging from 18.288 m (60 ft) (prototype) to a minimum length of 1.8288 m (6 ft). All dowels moved along the trash boom to the entrance to Unit 0. None of the 18.288-m (60-ft) (Photo 18) or 12.192-m (40-ft) (Photo 19) dowels passed into the ice and trash sluiceway. All smaller dowel sizes passed through to the ice and trash sluiceway. Without the

18.288-m (60-ft) and 12.192-m (40-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. A few of the 10.0584-m (33-ft) dowels hung between the two trash booms in the Unit 0 ice entrance when placed in the model by themselves.

Debris experiments were repeated with a mixture of 10.0584-m (33-ft), 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar, simulated ice, and root balls (Photo 20). Most of the debris traveled down the trash to the entrance to the ice and trash sluiceway at Unit 0. However, some of the larger pieces of cedar and root balls became entangled on the boom support strings and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse was pulled mainly to Units 1-2 and piled up against the backside of the boom. Some of the 8.2296-m (27-ft) and 10.0584-m (33-ft) dowels hung up at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0, blocking other debris from passing freely (Photo 21). If this did not happen, all debris that made it to Unit 0 passed freely into and through the ice and trash sluiceway.

Velocities measured along the trash boom for this condition and velocities obtained in the boat entrance can be seen in Plates 7-9. These velocities, debris experiments, and dye experiments (Photo 22) indicate that debris should not enter and that boats should be able to navigate into the opening.

Unit discharge = 382.293 cu m/sec (13,500 cfs); pool el = 71.5

Each of the 10 powerhouse units was set with a discharge of 297.339 cu m/sec (10,500 cfs) and the upper pool elevation was set at el 71.5. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were introduced to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels, which were introduced together and separately, had lengths ranging from 18.288 m (60 ft) (prototype) to a minimum length of 1.8288 m (6 ft). All dowels moved along the trash boom to Unit 0 the entrance. None of the 18.288-m (60-ft), 12.192-m (40-ft), or 10.0584-m (33-ft) (Photos 23 and 24) dowels passed into the ice and trash sluiceway. Some of the 8.2296-m (27-ft) dowels hung up in the ice and trash sluiceway and caused the smaller dowels to become lodged around them (Photo 25). However, without the 8.2296-m (27-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. Also a few of the 8.2296-m (27-ft) dowels hung between the two trash booms in the Unit 0 ice entrance when placed in the model by themselves.

Debris experiments were repeated with a mixture of 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar, and root balls. Most of the debris traveled down the trash boom (Photo 26) to the entrance to the ice and trash sluiceway at Unit 0. However, a significant portion of the larger pieces of cedar and root balls became entangled on the boom support strings and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom sections nearer the powerhouse was pulled mainly to units 1-2 and piled up against the backside of the boom (Photo 27). Some of the 8.2296-m (27-ft) and 10.0584-m (33-ft) dowels hung up at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0, blocking other debris from passing freely. If this did not happen, all debris that made it to Unit 0 passed through freely.

Trash Boom Anchor Cable Extensions

For each discharge and pool elevation, debris became entangled in the anchor cables. Experiments were performed to determine if it would be possible to add extension plates on the bottom of the anchor floats to move the attachment cable deeper in the water to reduce the entanglement of debris on the anchor cable. The extension plate lowered the attachment point 2.4384 m (8 ft) deeper into the water column for a total depth of 3.3528 m (11 ft). Debris experiments were conducted for discharges of 297.339 and 382.293 cu m/sec (10,500 and 13,500 cfs) with a forebay of 22.7076 m (74.5 ft) (Photos 28-30). While the lower attachment point reduced the amount of debris interference, it did not reduce it significantly. It was thought that it would not be practical to extend the point any lower in the water column; therefore experiments with attachment depths greater than 3.3528 m (11-ft) were not pursued.

Final Trash boom alignment

Configuration

The trash boom was modified to shorten its length to approximately 335.2800 m (1,100 ft). The shortened trash boom was divided into four sections, each section consisting of six 12.192-m- (40-ft-) long boom pieces. The sections were separated by and attached to an anchor float. All boom pieces and anchor floats were strung together with braided fishing line. It was determined that the steel cable used to string the original trash boom together was too stiff and did not allow enough scallop to develop in the boom sections. The braided fishing line was less rigid and allowed for more scallop in each section, which would allow the boom arrangement to be closer to what would be expected in the prototype. New trash boom support pipes were driven into the topography approximately 91.44 m (300 ft) downstream of the original pipes. The downstream end of the trash boom was attached by eye-hooks to the powerhouse face (same position as the original trash boom) at the Unit 0 end and to the most upstream pipe of the three newly installed pipes. This final arrangement resulted in a rotation of 7.4 deg toward the powerhouse compared to the original alignment or a 42.6-deg angle with respect to the powerhouse. Each anchor float was attached to the invert of the channel and the upstream side of the anchor float by braided fishing line. Attached to the most upstream of the three newly installed pipes was a wooden boom constructed from 1.0668-m- (3.5-ft-) diameter dowels. The new pipes and wooden boom arrangement formed a boat entrance (Figure 13). The 73.1520-m- (240-ft-) long trash boom between Unit 0 and the old navigation lock was not changed. In addition to changes in the trash boom, the area downstream of Unit 0 was modified. A triangular wedge was added to the invert of the ice and trash sluiceway to help the debris to be directed down the sluiceway immediately after debris passed over the Unit 0 sluice gate. A metal shroud was added to the area downstream of the ice and sluiceway entrance to simulate the proposed add-in water supply pipe. Also, a ceiling was added to the channel downstream of the ice and sluiceway and the downstream channel was narrowed to simulate the correct prototype geometry more accurately.

Experiments

Each of the 10 powerhouse units was set with a discharge of 297.339 cu m/sec (10,500 cfs) and the upper pool was set at el 74.5. All sluiceway gates were closed except for Unit 0, which was open to el 68.0. Wooden dowels were added to the model upstream of the boat entrance and just downstream of the upper limits of the model. These dowels had lengths ranging from 18.288 m (60 ft) (prototype) to a minimum length of 1.8288 m (6 ft). These dowels were introduced together and separately. All dowels moved along the trash boom to the Unit 0 entrance. None of the 18.288-m (60-ft) (Photo 32) or 12.192-m (40-ft) dowels passed into the ice and trash sluiceway. Some of the 10.0584-m (33-ft) dowels were caught in the ice and trash sluiceway and caused the smaller dowels to become lodged around them. However, without the 10.0584-m (33-ft) dowels in the debris mixture, all the dowels passed through the ice and trash sluiceway. Also a few of the 8.2296-m (27-ft) dowels hung between the two trash booms in the Unit 0 ice entrance when placed in the model by themselves. The wedge piece that was added downstream of the entrance of Unit 0 improved the passage of debris through the ice and trash sluiceway. Also, various lengths of 1.0668-m (3.5-ft) diameter dowels were put into the model and allowed to progress along the boom. Dowels smaller than 8.2296 m (27 ft) passed through the Unit 0 sluice gate while 8.2296 m (27 ft) and longer did not (Photo 33).

Debris experiments were repeated with a mixture of 8.2296-m (27-ft), 6.096-m (20-ft), and 3.9624-m- (13-ft-) long dowels in combination with wet cedar, dry cedar and root balls. Debris was introduced into the model above the trash boom. As the debris traveled down the trash boom it collected in each scallop (Photo 34). It continued to build until some debris sheared off and moved down to the next scallop (Photo 35). Finally the debris reached the entrance to the ice and trash sluiceway at Unit 0 (Photo 36). Some of the larger pieces of cedar and root balls became and remained entangled on the boom support strings and some of the larger wet debris was pulled under the boom. The debris pulled under the trash boom at the upstream sections of the trash boom moved to powerhouse Units 7-10. The debris passing under at trash boom

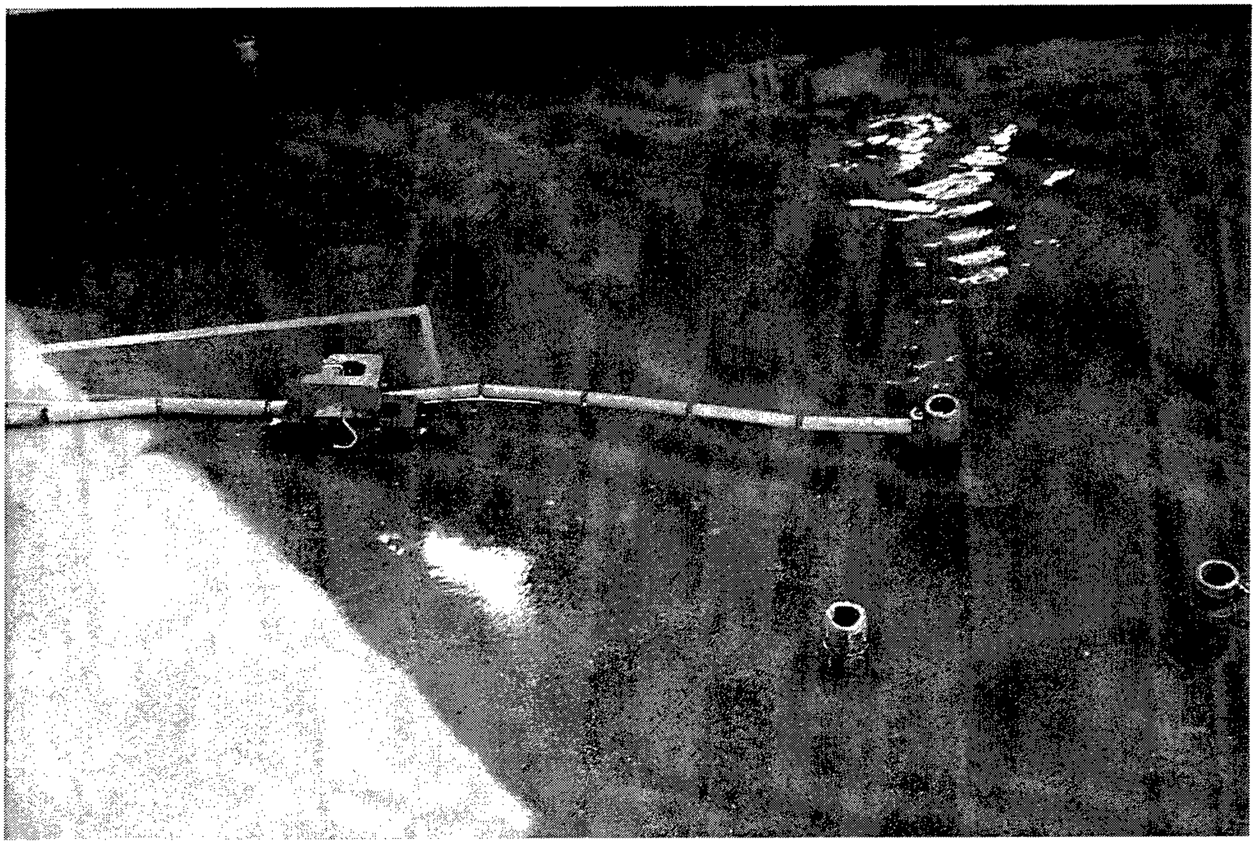


Figure 13. Boat entrance and wooden boom for final boom alignment

sections nearer the powerhouse was pulled mainly to Units 1-2 and piled up against the backside of the boom. Some of the 8.2296-m (27-ft) dowels were caught at the entrance to the ice and trash sluiceway by turning sideways before entering Unit 0, blocking other debris from passing freely. If this did not happen, all debris that made it to Unit 0 passed freely into and through the ice and trash sluiceway. Some of the debris remained in the scallops after the experiment was over.

Velocities measured along the trash boom and in the boat entrance for this condition and for a unit discharge of 297.339 cu m/sec (10,500 cfs) are shown in Plates 10-12 and for a unit discharge of 382.293 cu m/sec (13,500 cfs) in Plates 13-15. Velocities were obtained near the surface and at depths of 1.5290 and 3.0480 m (5 and 10 ft). These velocities were measured so the potential loading on the trash boom could be calculated and the trash shear velocity could be determined. These velocities, debris experiments (Photo 8), and dye experiments (Photo 9) indicate that debris should not enter and that boats should be able to navigate into the opening.

4 Conclusions and Recommendations

The original trash boom arrangement worked well for capturing and moving debris to the Unit 0 sluiceway opening. In all pool elevations and unit discharges, some of the wet debris became entangled in the anchor support cables. The cable attachment point was lowered an additional 2.4384 m (8 ft) and the frequency of entanglement improved, but was not alleviated, which will have to be addressed during the final design of the trash boom or at the prototype structure if it becomes a problem once the trash boom is installed. The boat entrance appeared to allow for boat access to the powerhouse and still keep debris from bypassing the trash boom.

The final design trash boom worked adequately for capturing and moving debris to the Unit 0 sluiceway opening. In all pool elevations and unit discharges, some of the wet debris became entangled in the anchor support cables just as it did in the original trash boom configuration. The cable attachment point was lowered an additional 2.4384 m (8 ft) and the frequency of entanglement improved, but was not alleviated, which will have to be addressed during the final design of the trash boom or at the prototype structure if it becomes a problem once the trash boom is installed. Also, because of the decreased angle of the trash boom to the flow and the additional scallop in the trash boom, trash collected along the boom in each scallop. Trash may collect in each scallop, but probably would not be a problem once the boom is installed because most of the debris eventually moved to the Unit 0 sluiceway opening. Debris passed through the Unit 0 ice and trash sluiceway opening easier for this design than the original design. The overall performance of original design trash boom was better, but the final design is shorter and should cost less to fabricate and install in the prototype, and it did perform satisfactorily for the conditions tested. The majority of the debris passed through Unit 0 for both trash boom configurations. Debris longer than 12.192 m (40 ft) (0.4572-m- (1.5-ft-) diameter) or 10.0584 m (33 ft) (1.0668-m- (3.5-ft-) diameter or larger) will not pass though the sluiceway. The larger debris will either have to removed or cut into smaller pieces to pass into the sluiceway. It is recommended that the invert area of the ice and trash sluiceway be modified to be include a triangular insert to assist the debris in passing the Unit 0 sluiceway.

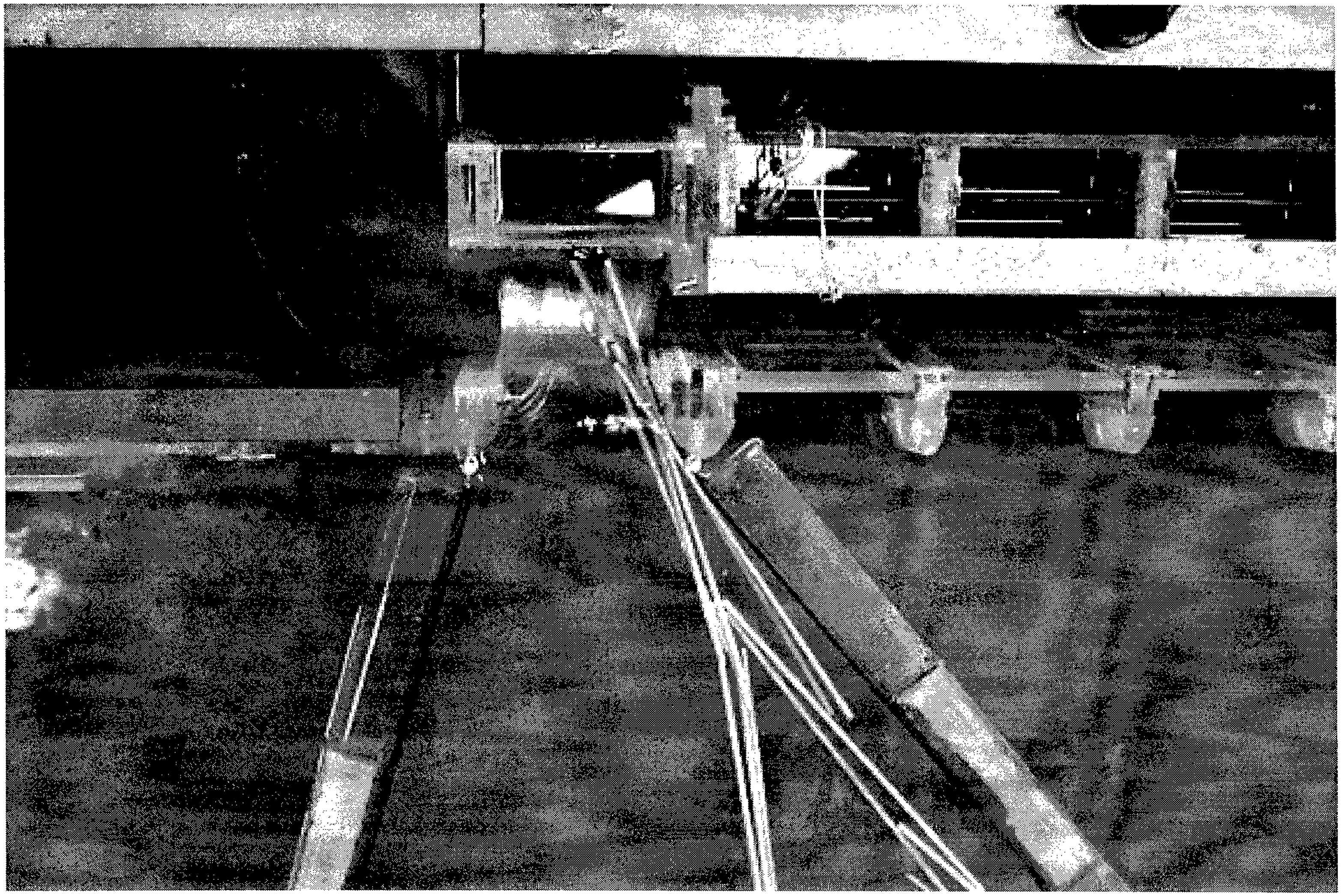


Photo 1. 60-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.399 cu m/sec (10,500cfs); pool el 77.0

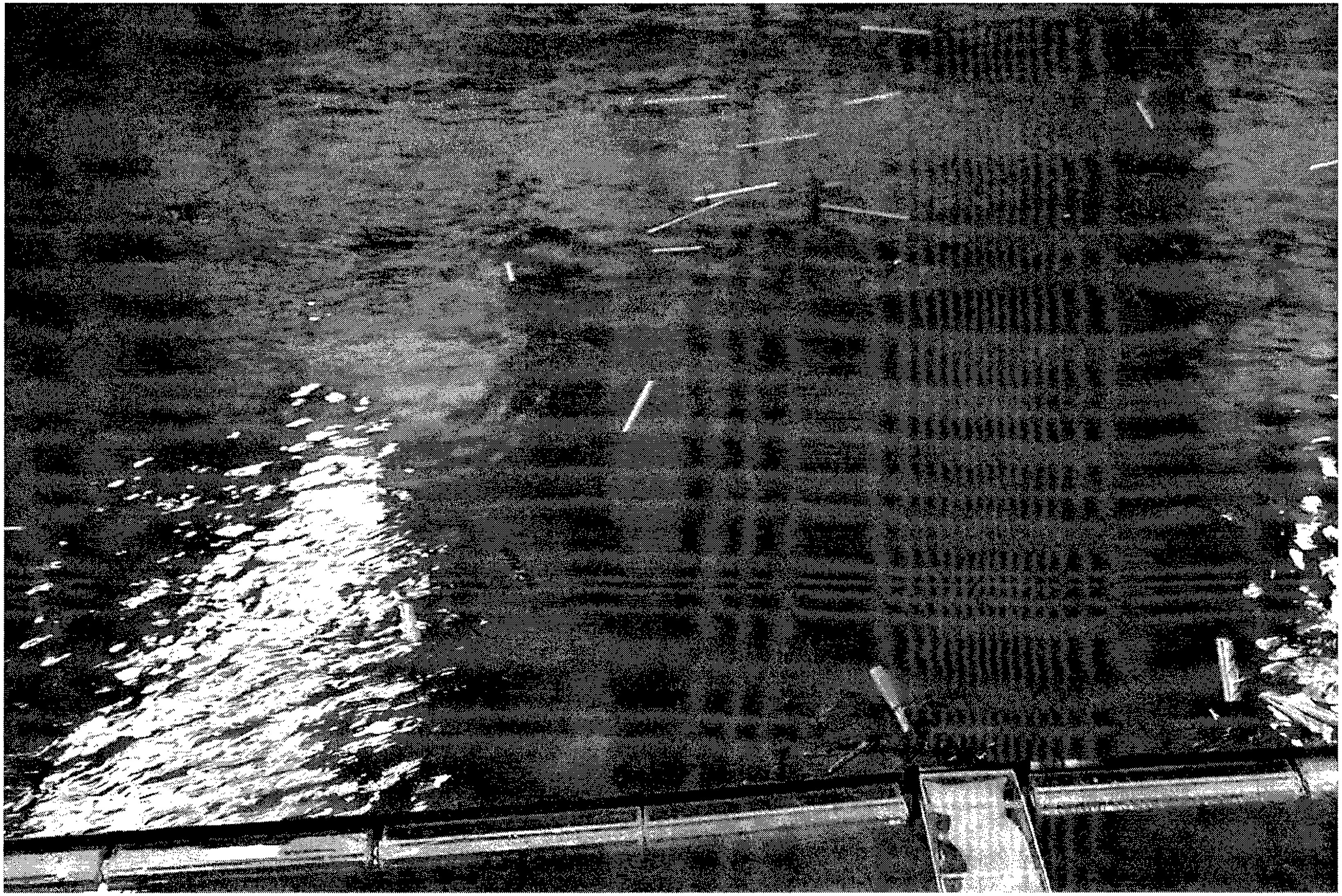


Photo 2. Debris along trash boom; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 77.0

Photo 3. Wet debris passing under trash boom; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 77.0

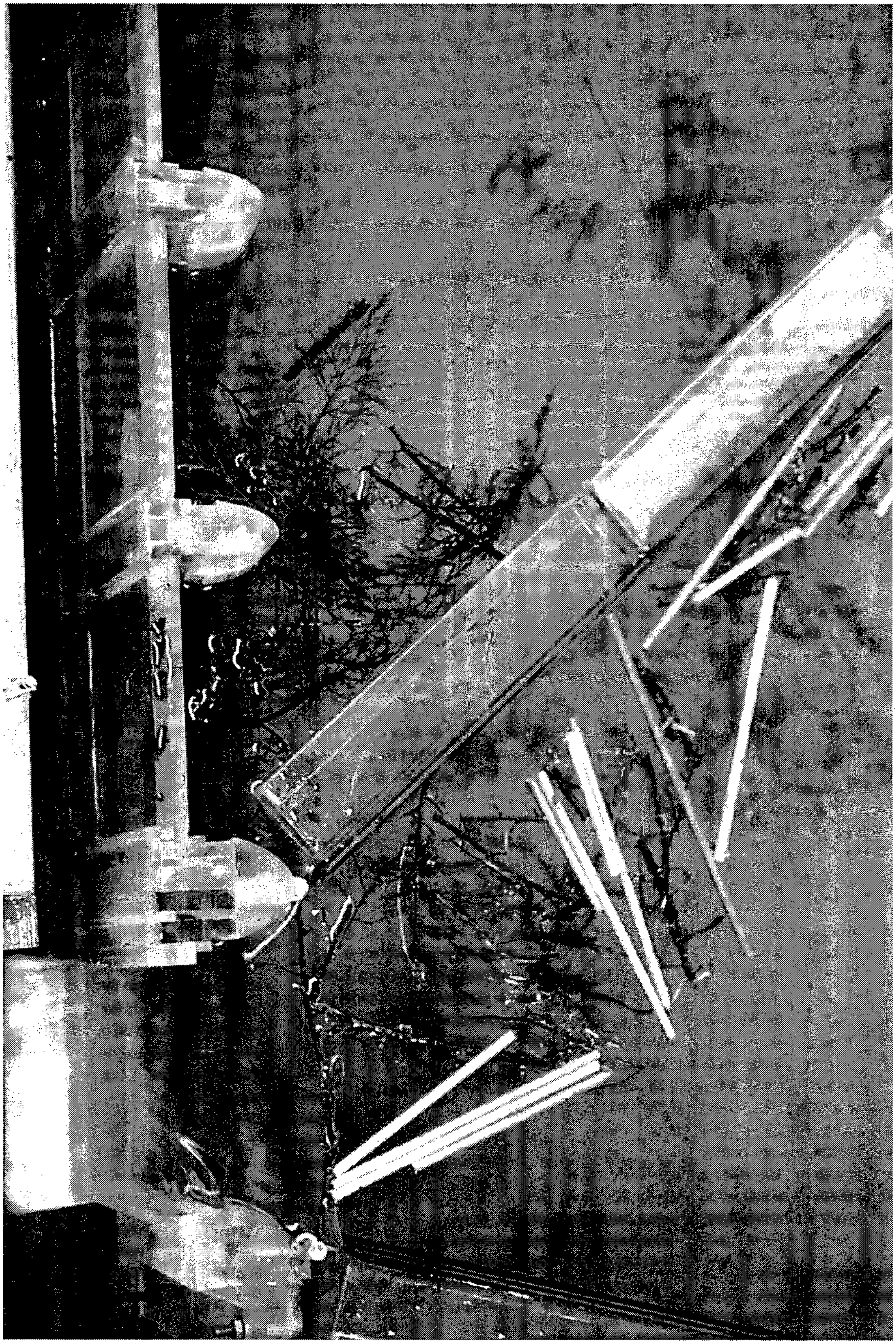


Photo 4. Debris at powerhouse Unit 1 and in Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 77.0

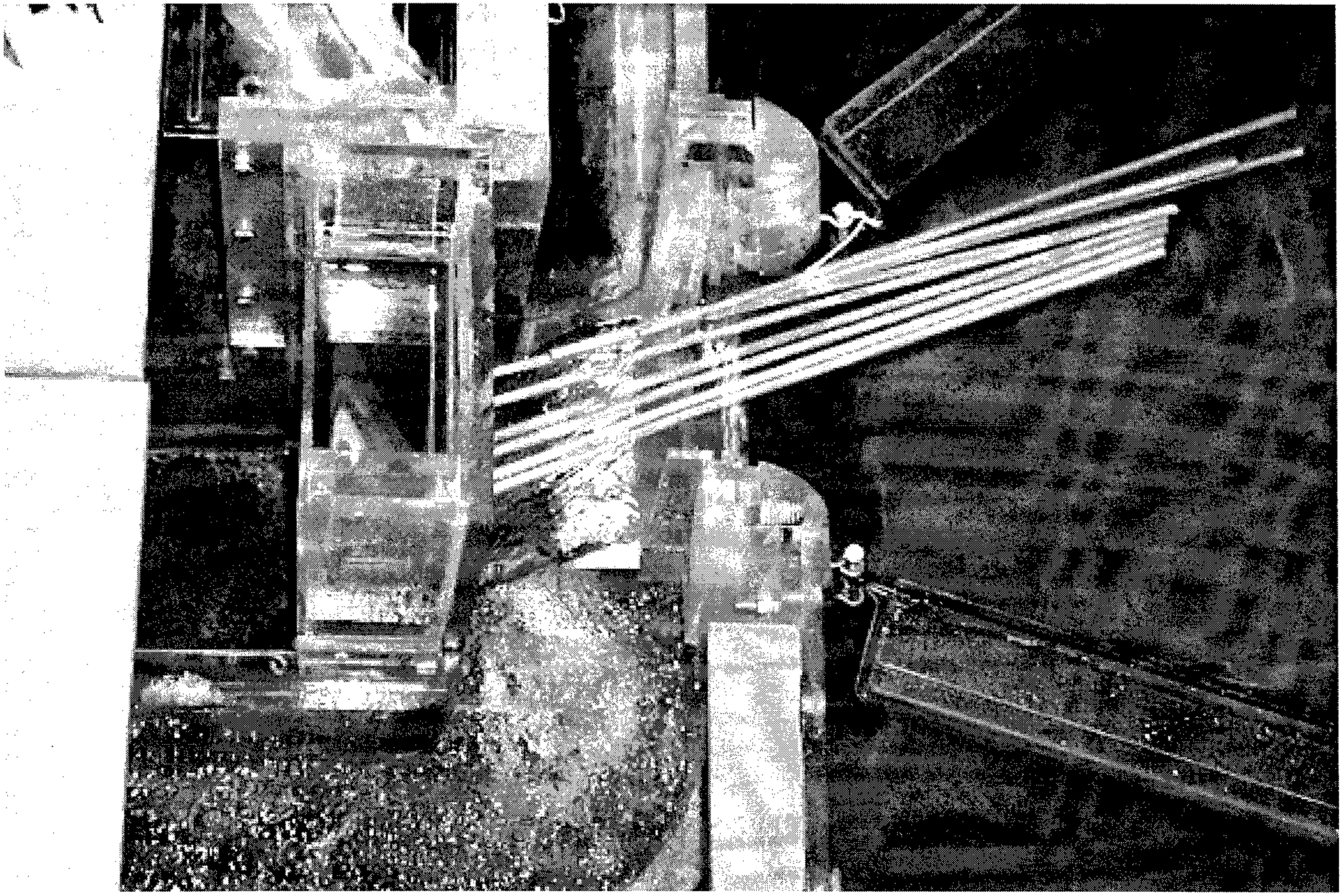


Photo 5. 60-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

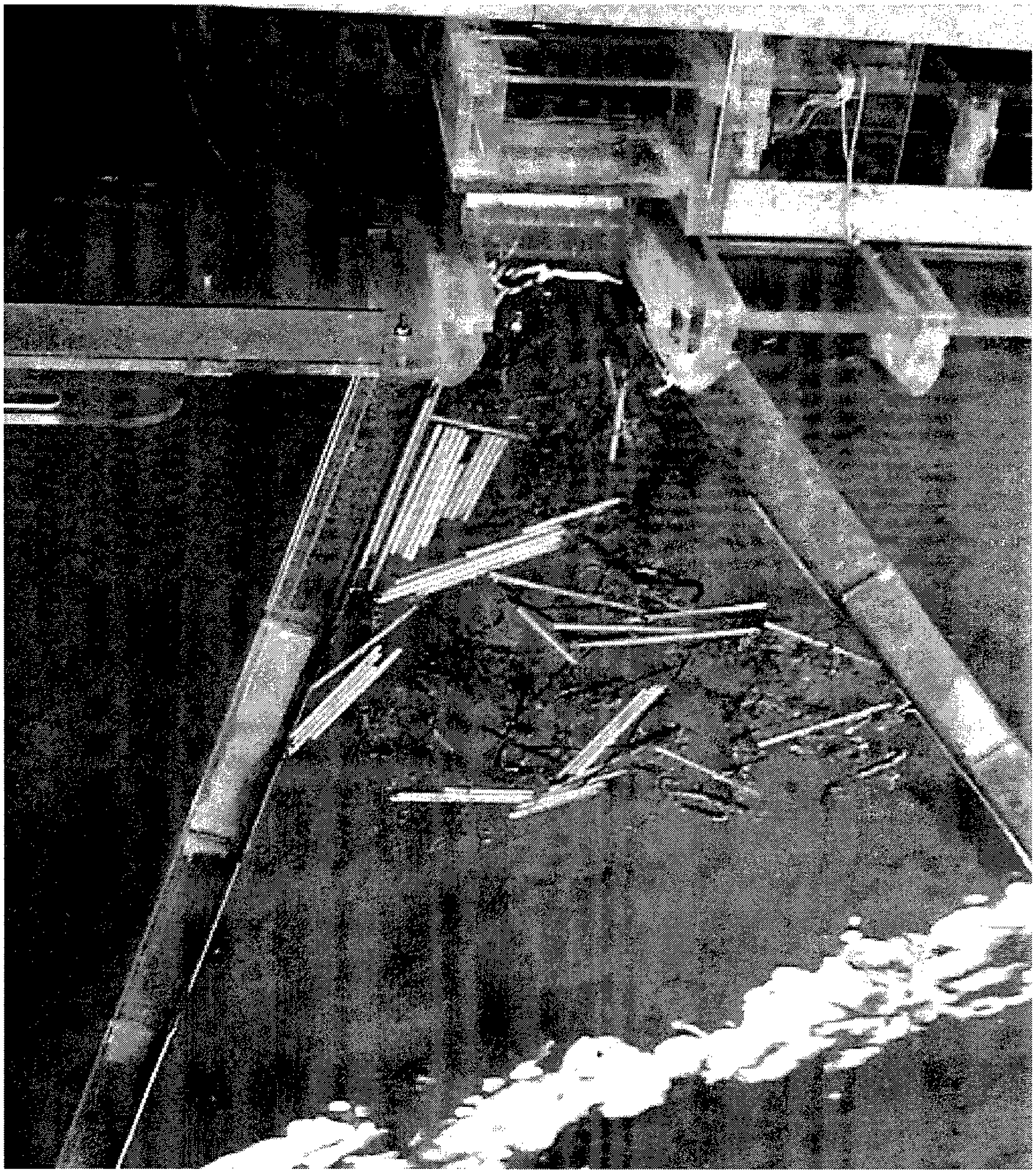


Photo 6. Various debris at powerhouse Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

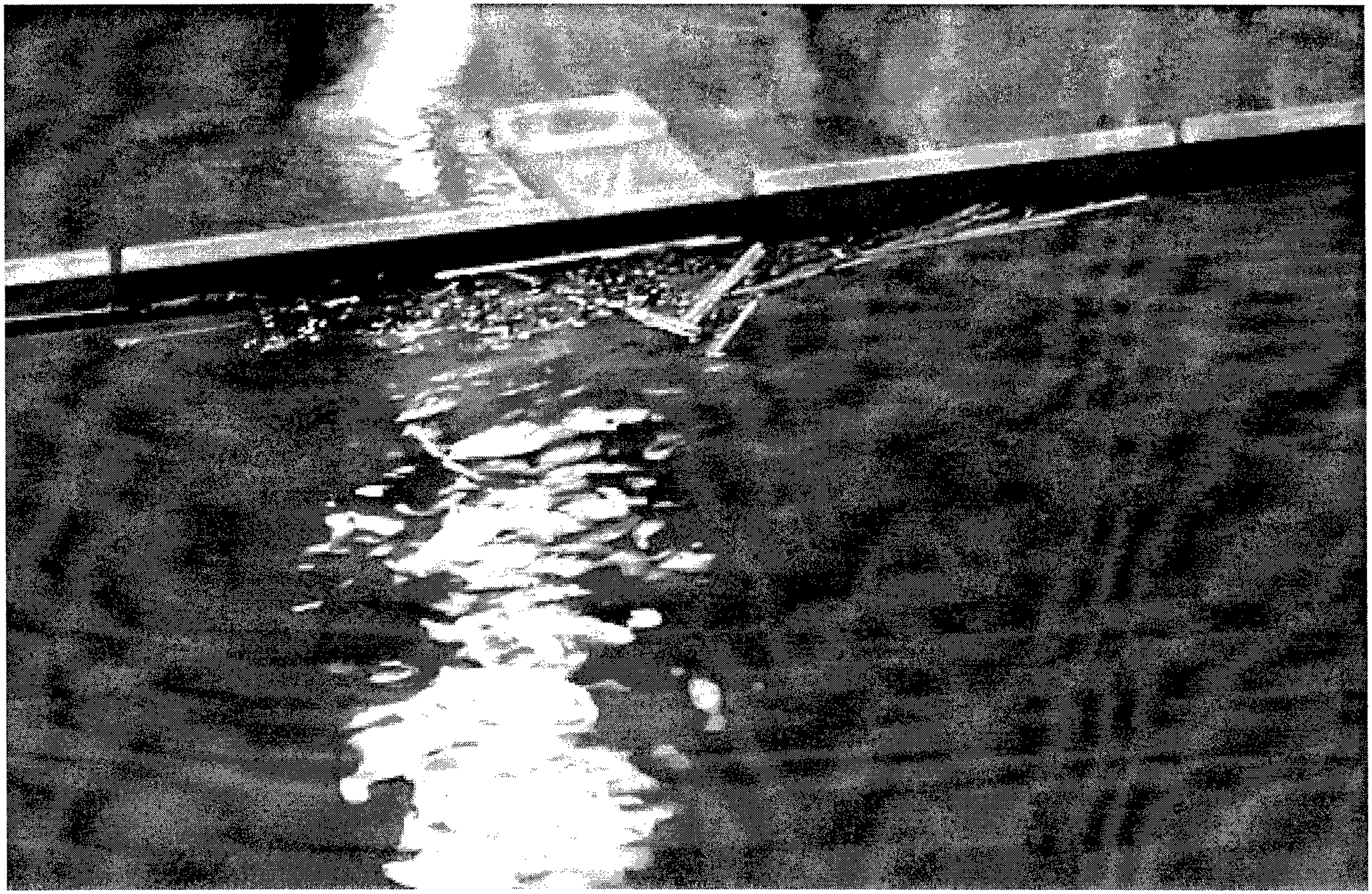


Photo 7. Debris entangled with anchor cable; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

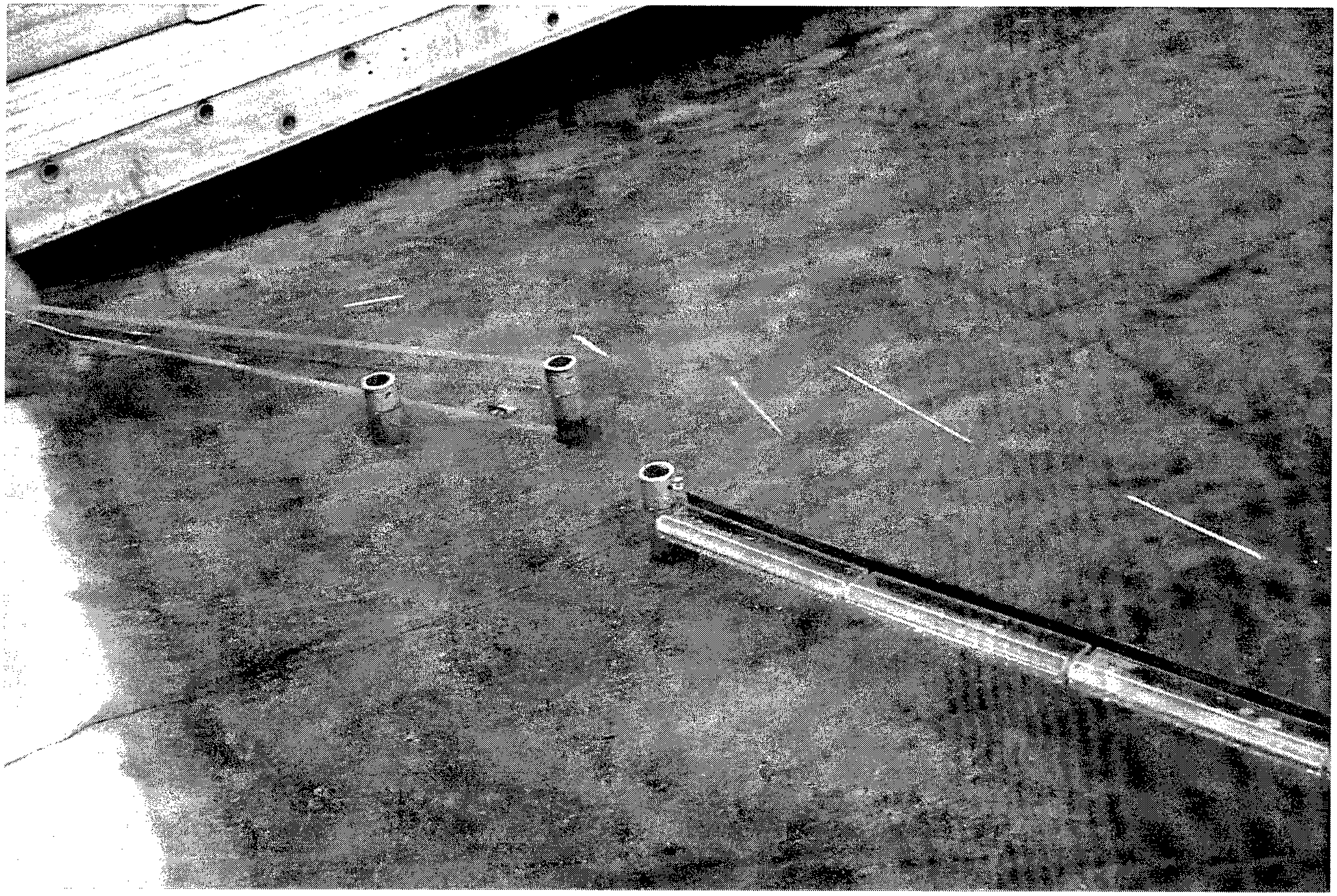


Photo 8. Debris experiments at boat entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

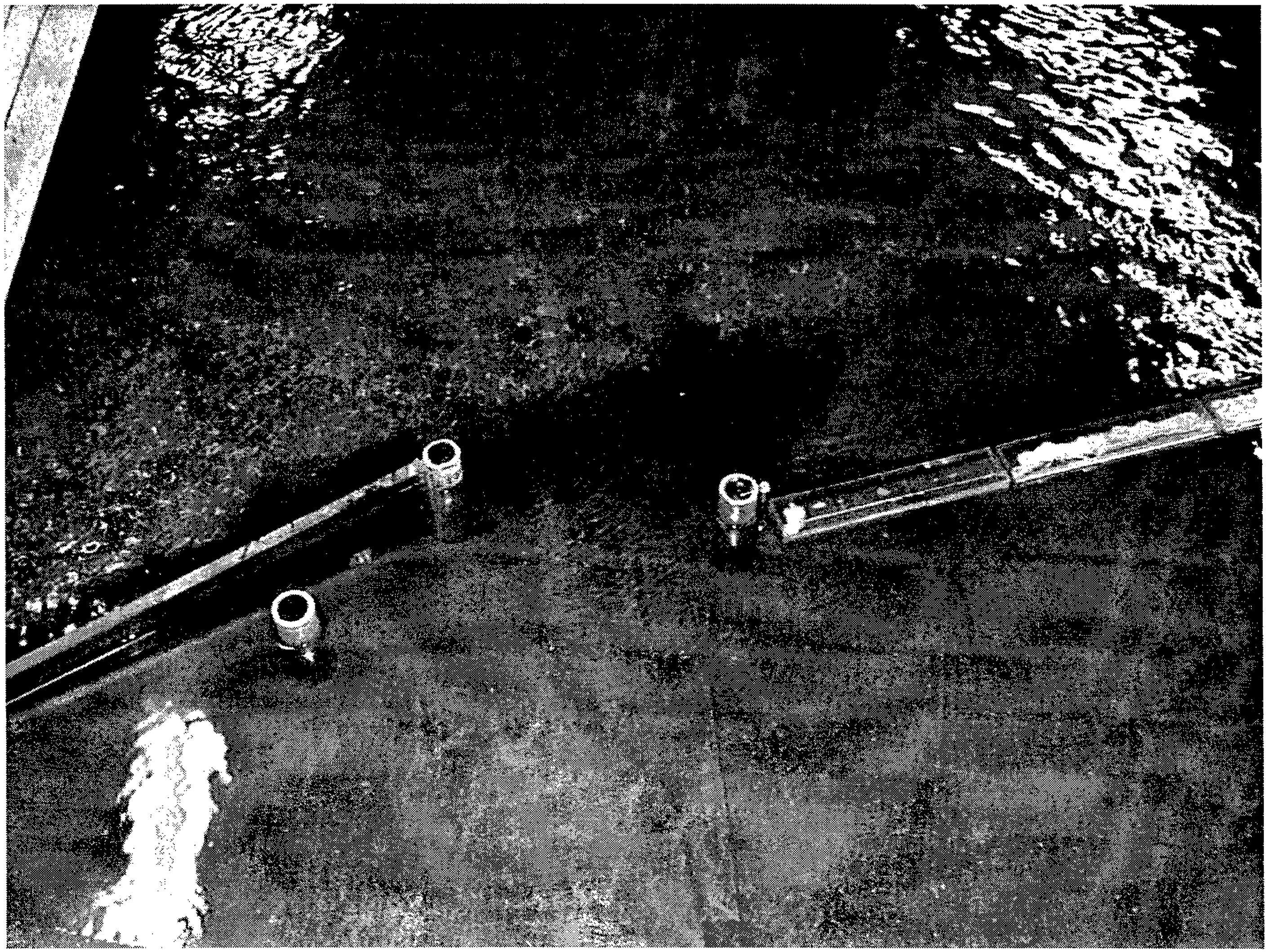


Photo 9. Dye experiments at boat entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

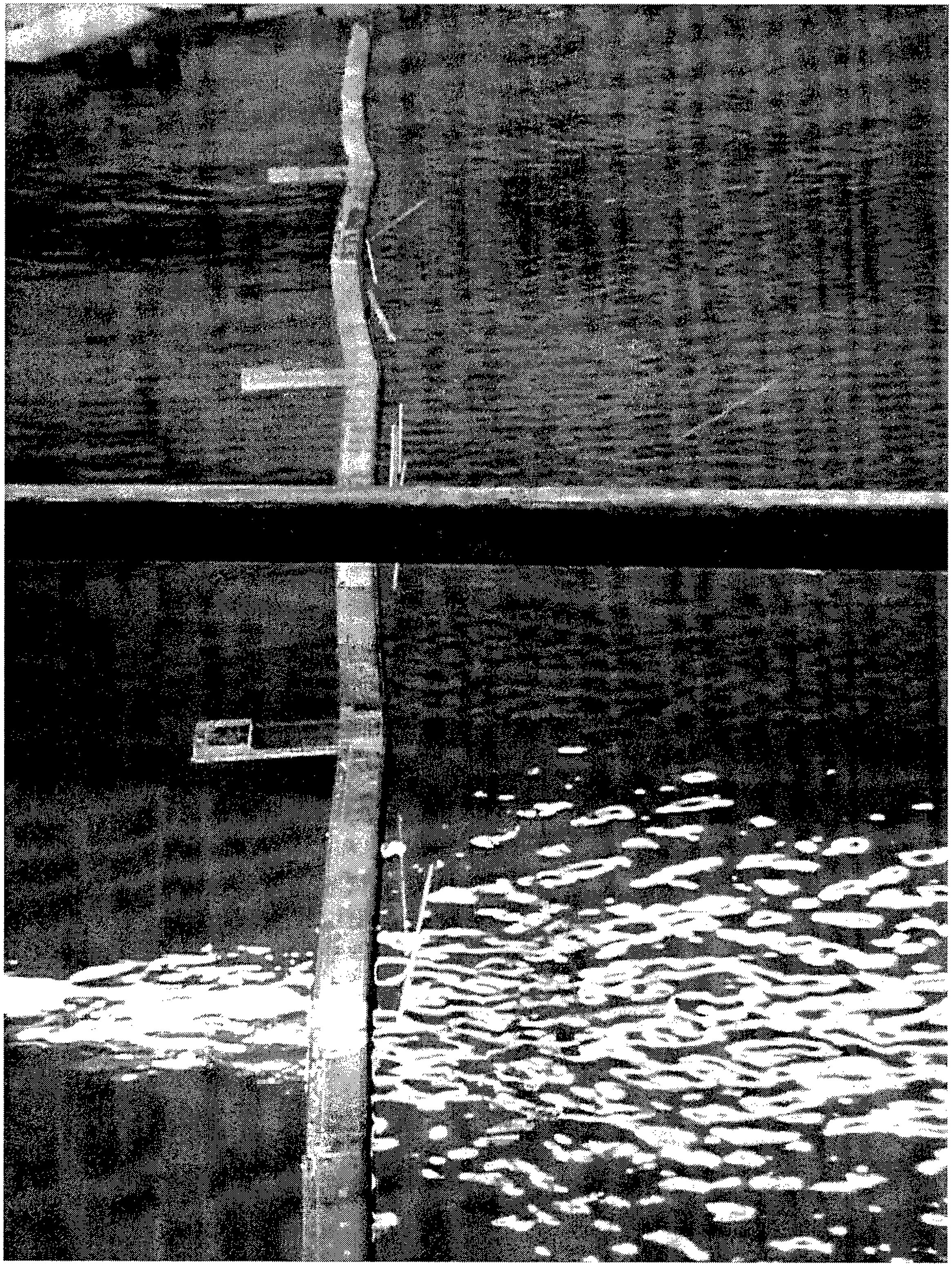


Photo 10. Dowels moving along trash boom; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 71.5

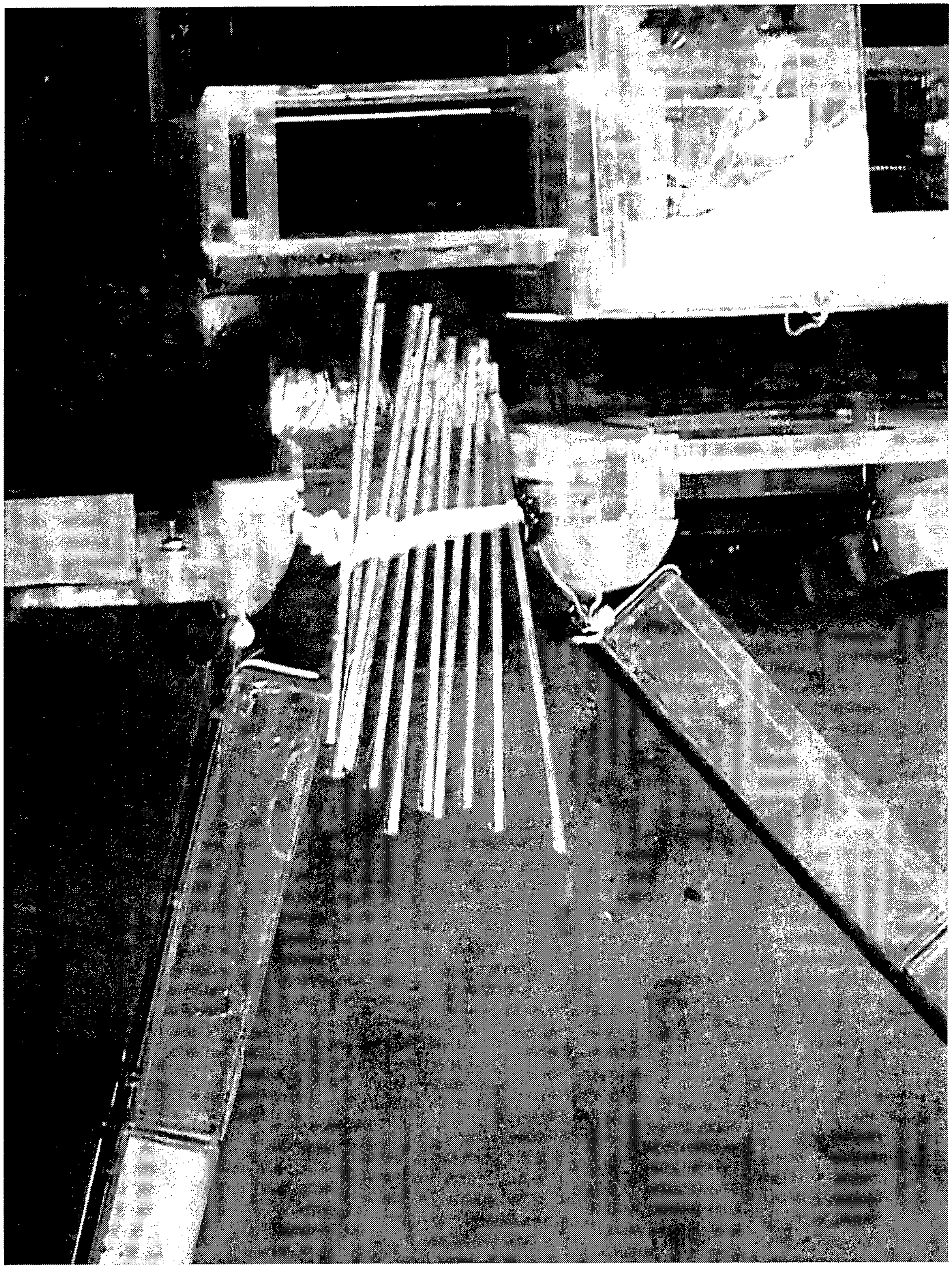


Photo 11. 40-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 71.5

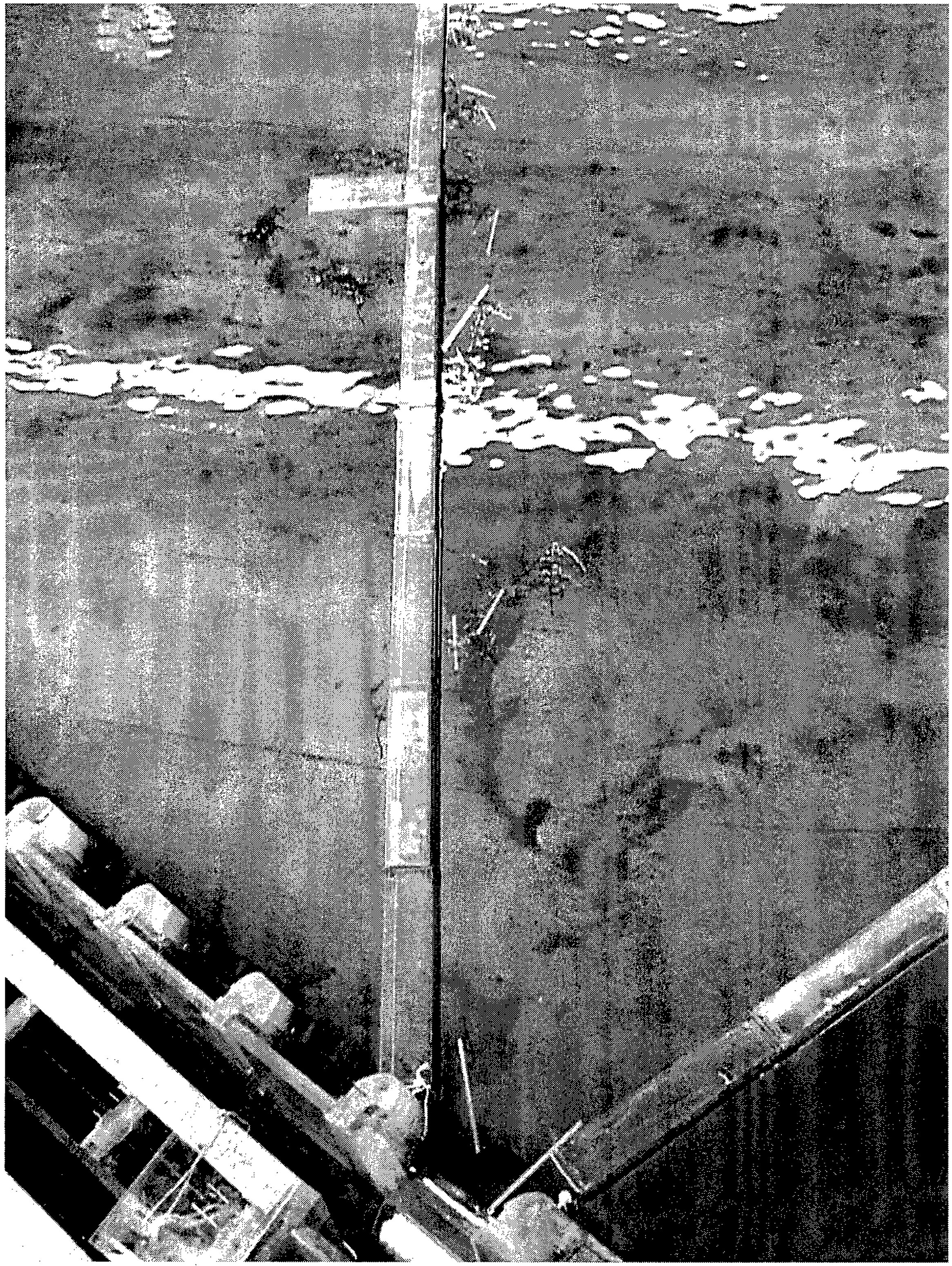


Photo 12. Debris at powerhouse Unit 1 and Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 71.5

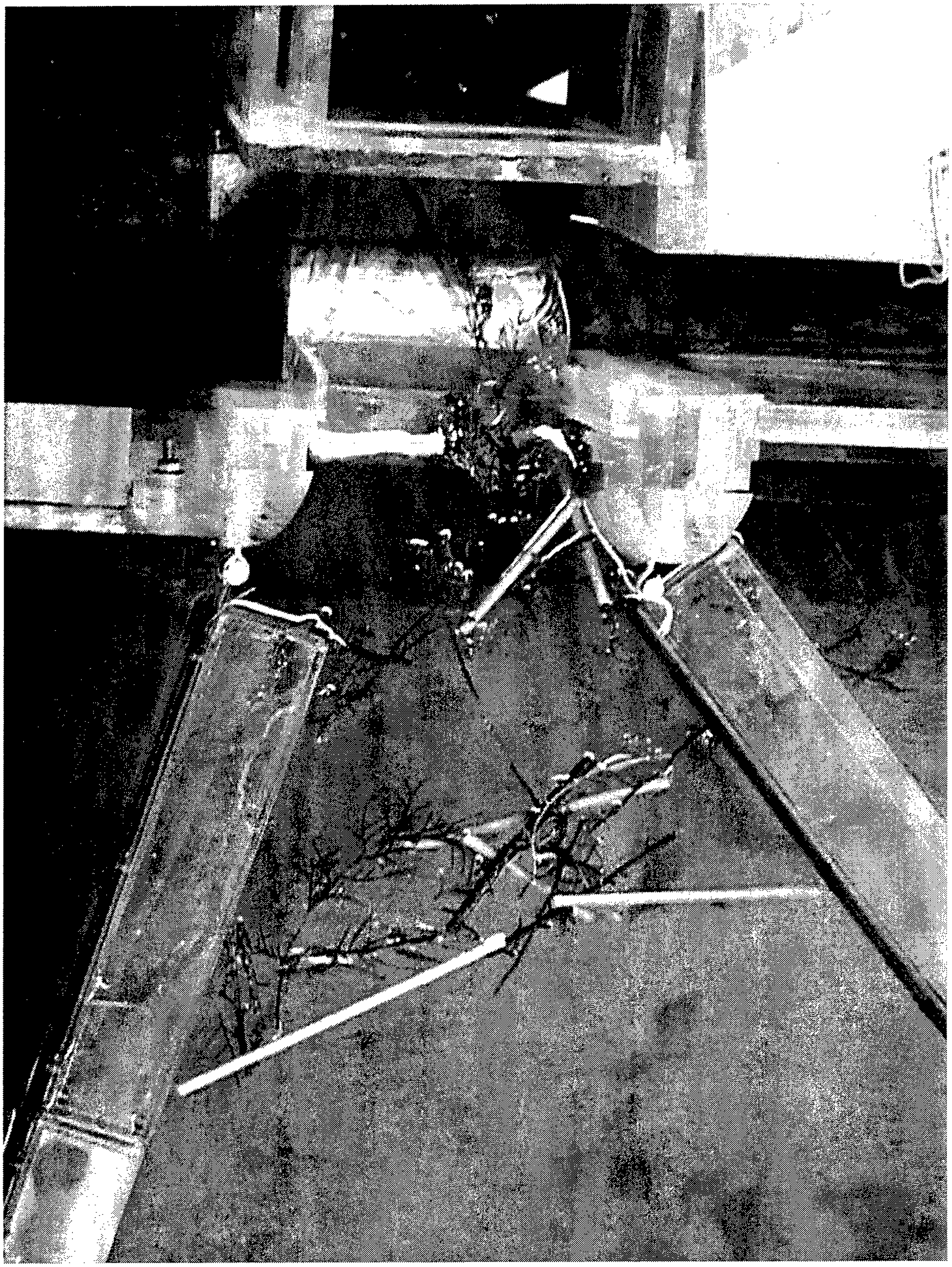


Photo 13. Debris at powerhouse passing through Unit 0 sluiceway entrance; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 71.5

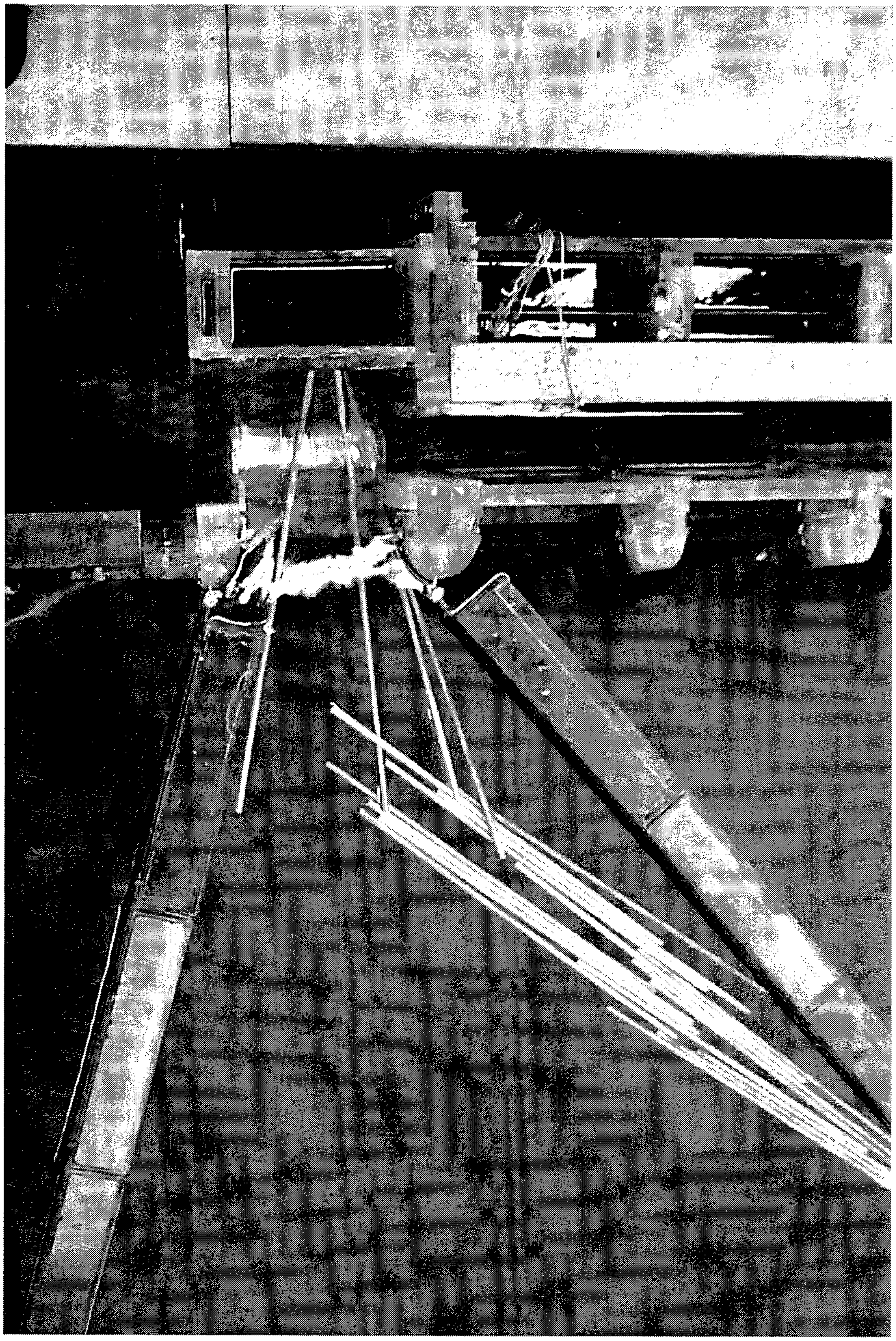


Photo 14. 60-ft dowers at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 77.0

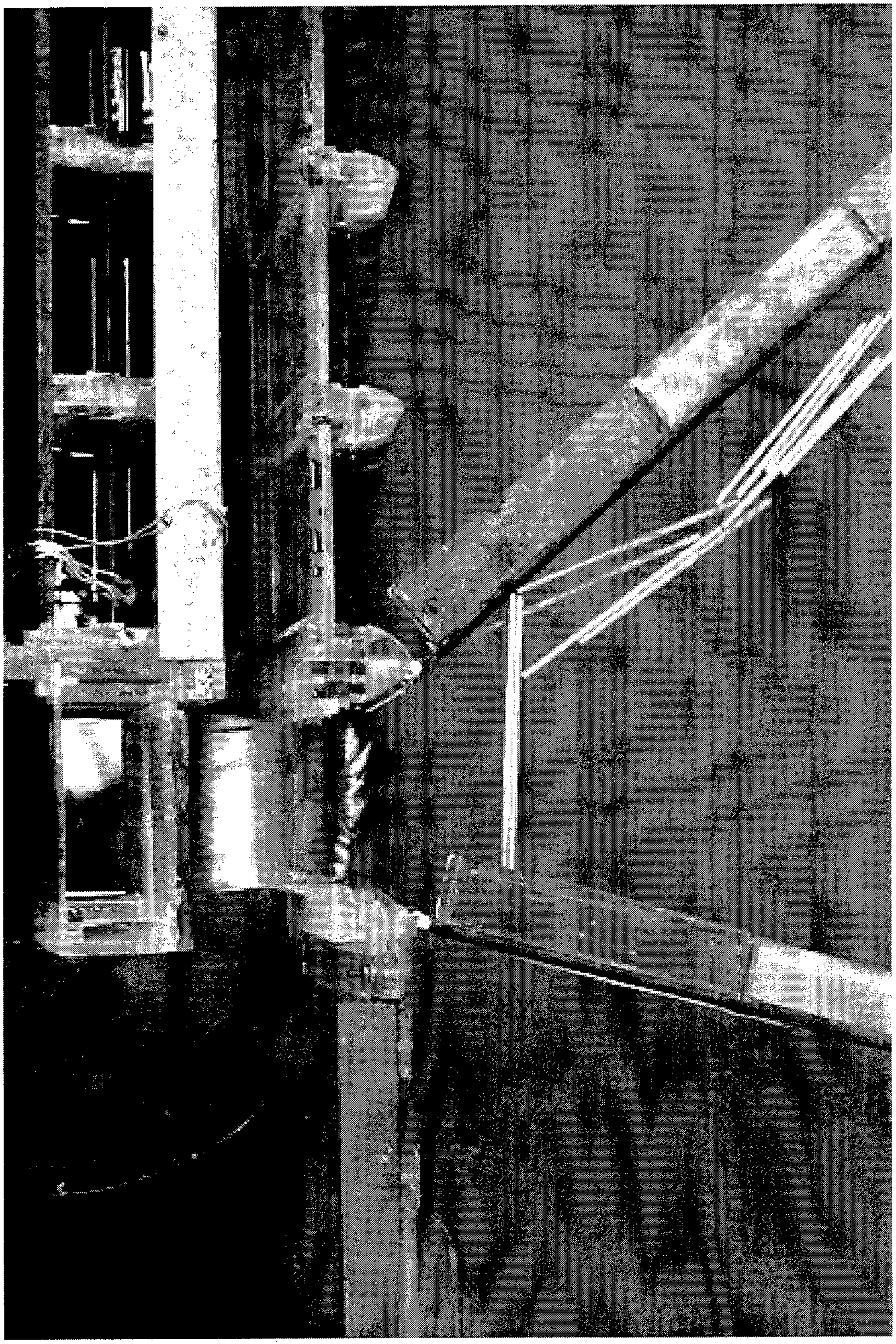


Photo 15. Dowels blocking Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 77.0

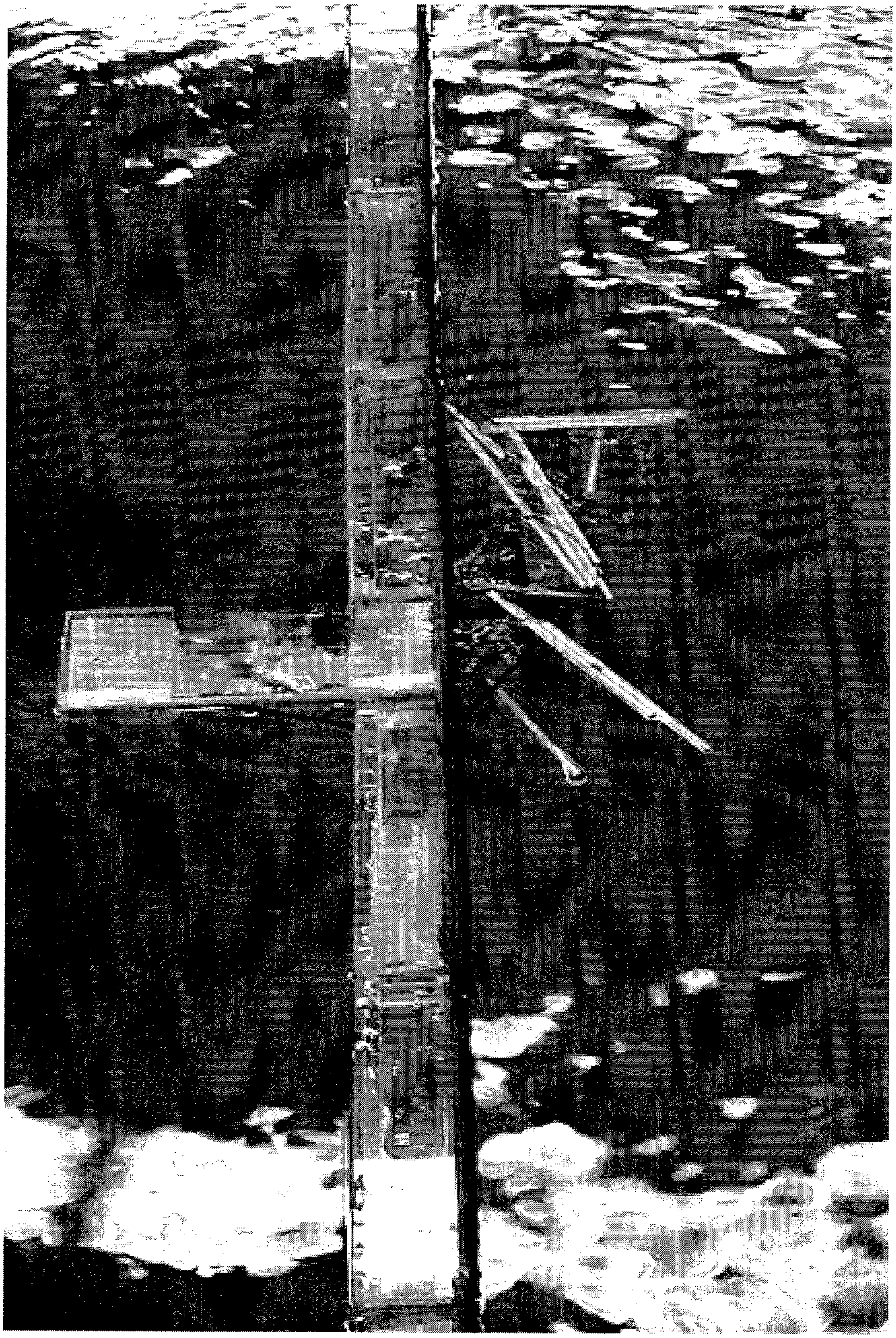


Photo 16. Debris entangled with anchor cable; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 77.0

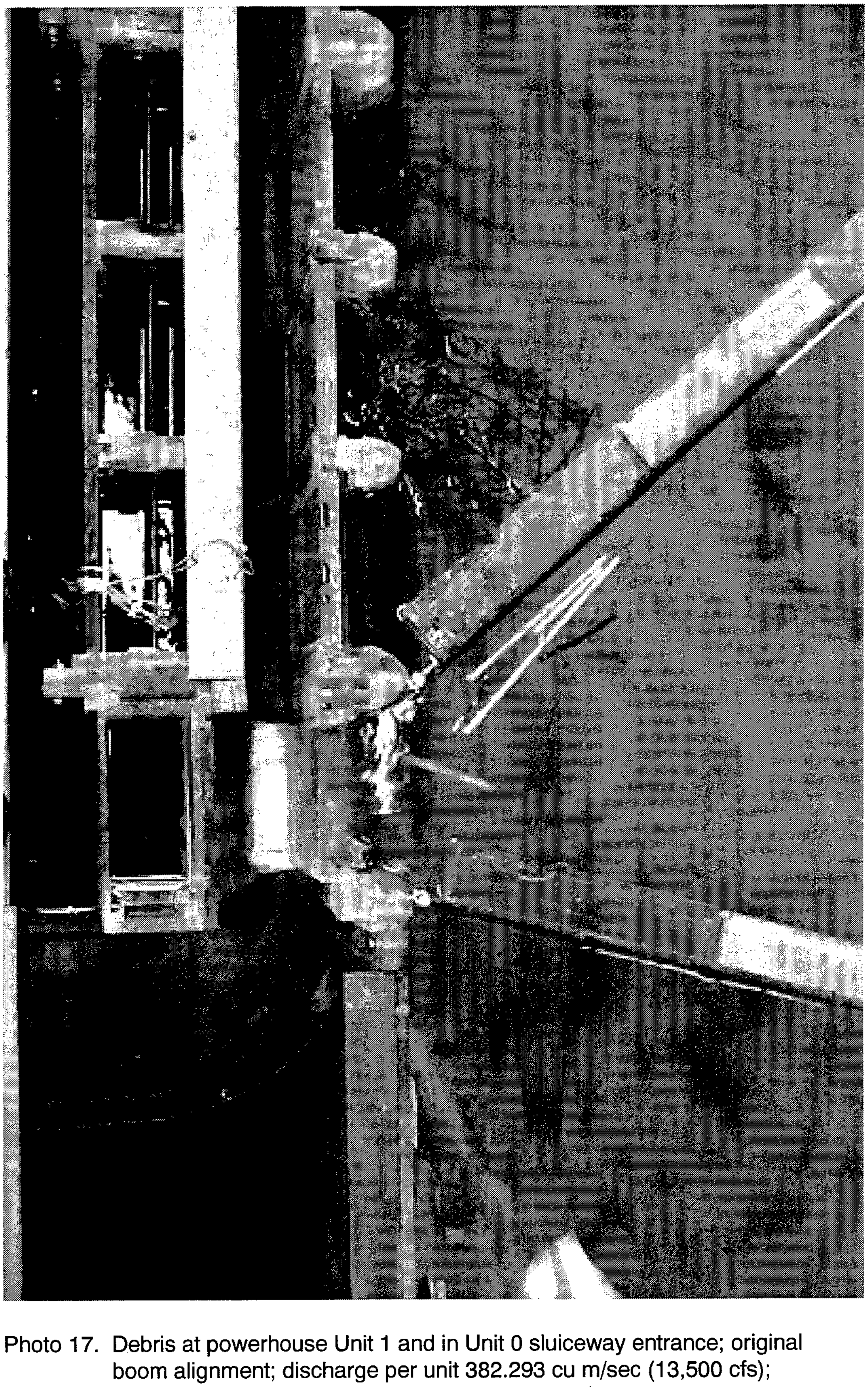


Photo 17. Debris at powerhouse Unit 1 and in Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 77.0

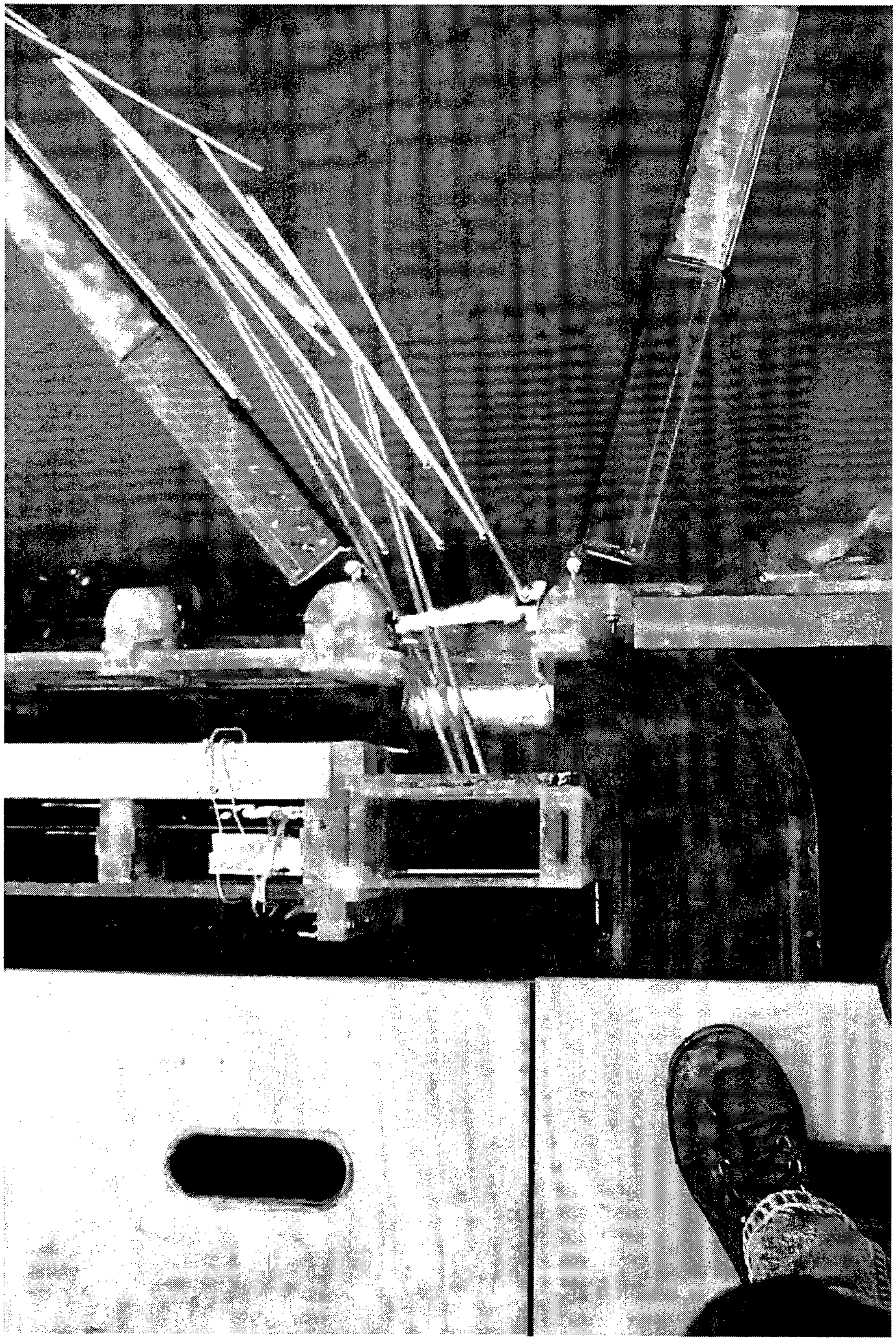


Photo 18. 60-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 74.5

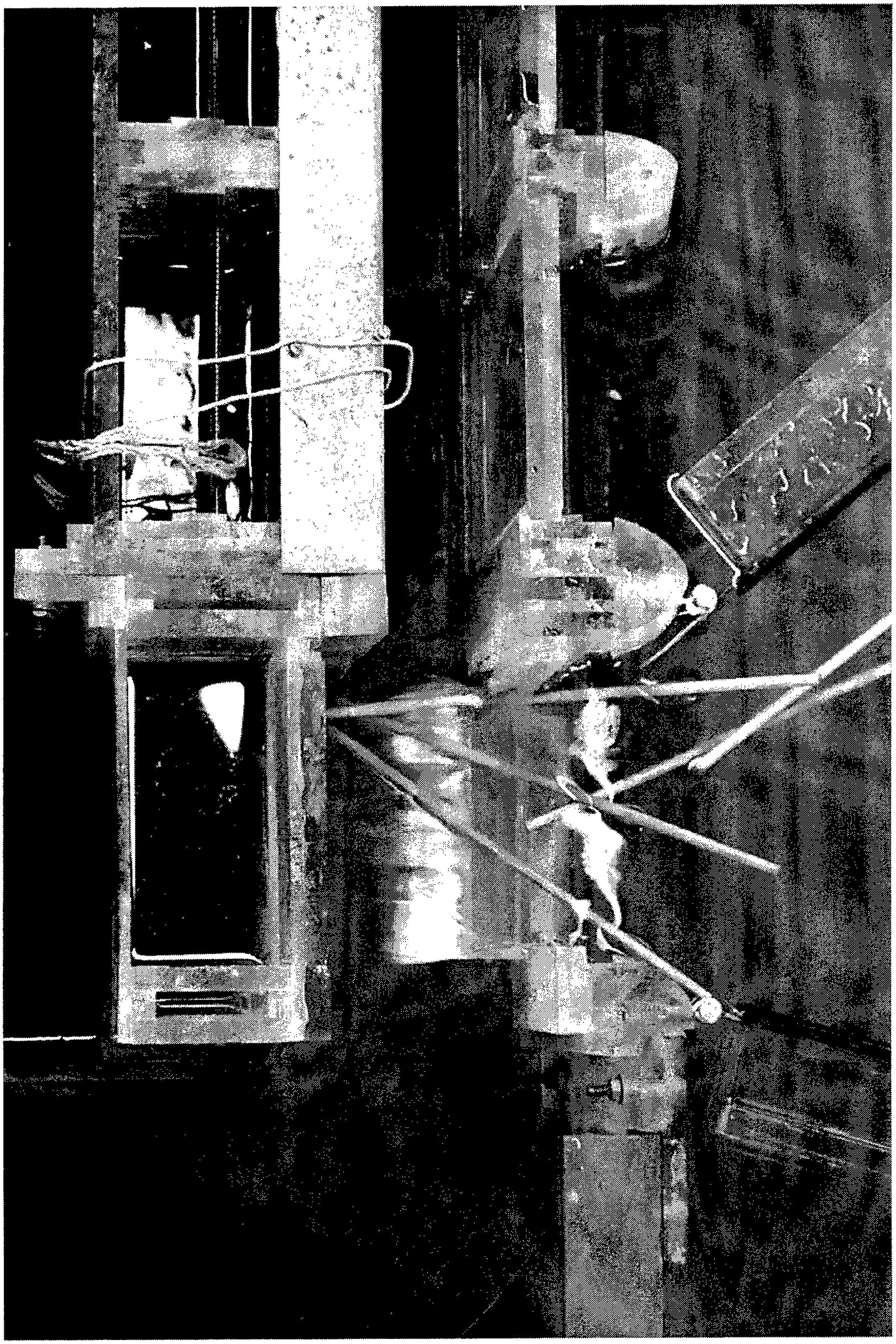


Photo 19. 40-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 74.5

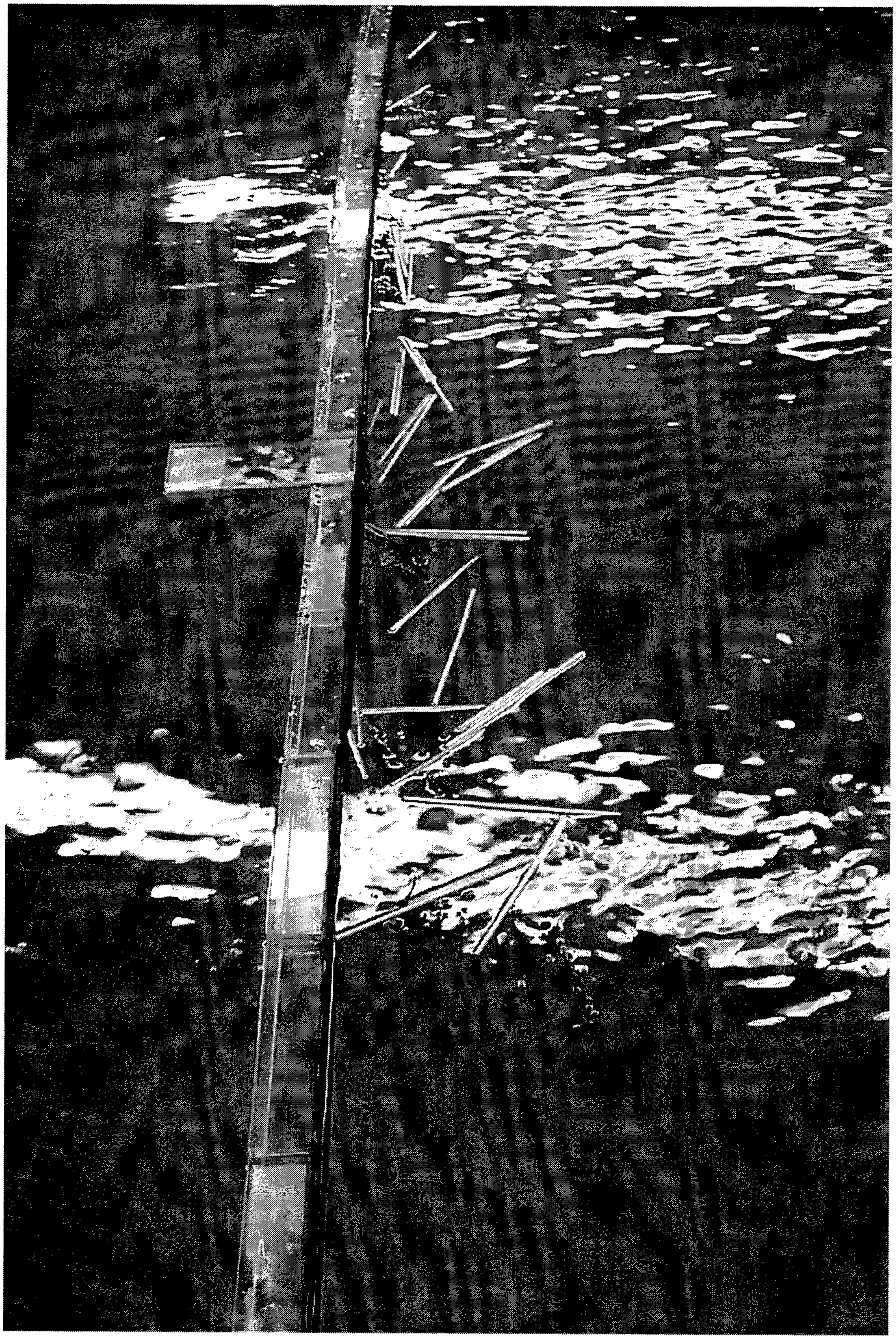


Photo 20. Various debris moving along trash boom; original boom alignment; dicharge per unit 382.293 cu m/sec (13,500 cfs); pool el 74.5

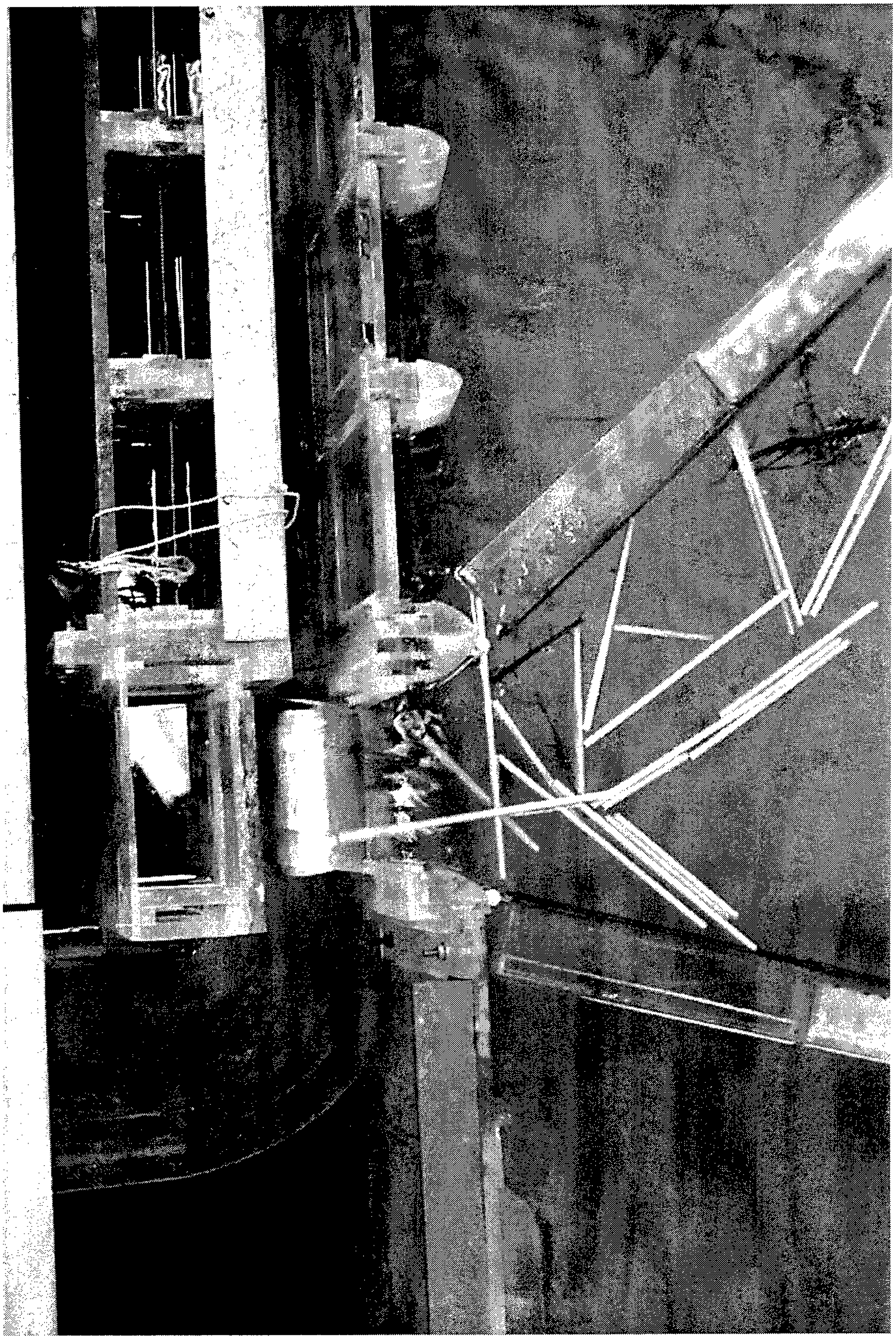


Photo 21. Dowels blocking Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 74.5

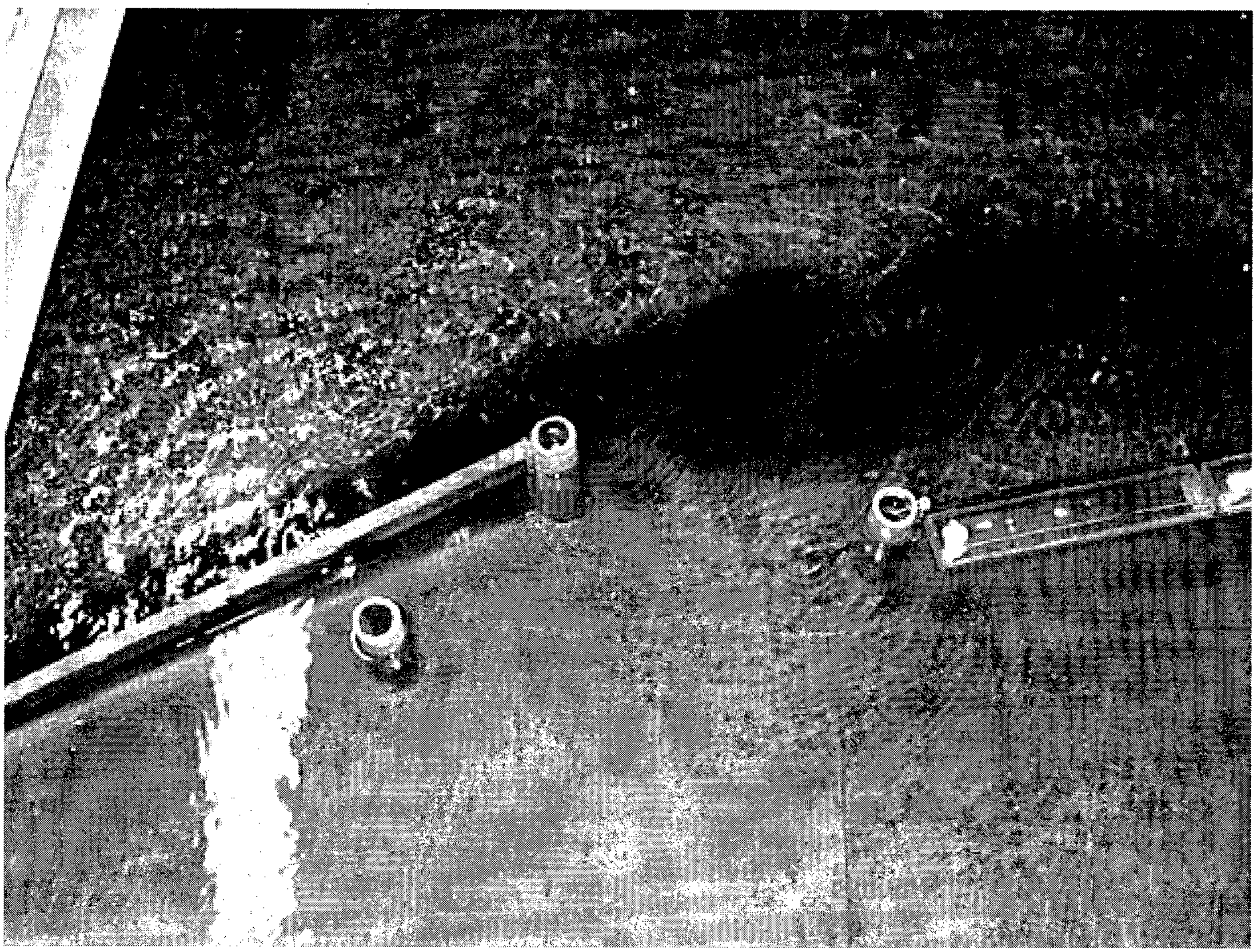


Photo 22. Dye experiments at boat entrance; original boom alignment; discharge per unit 382.293 (13,500 cfs); pool el 74.5

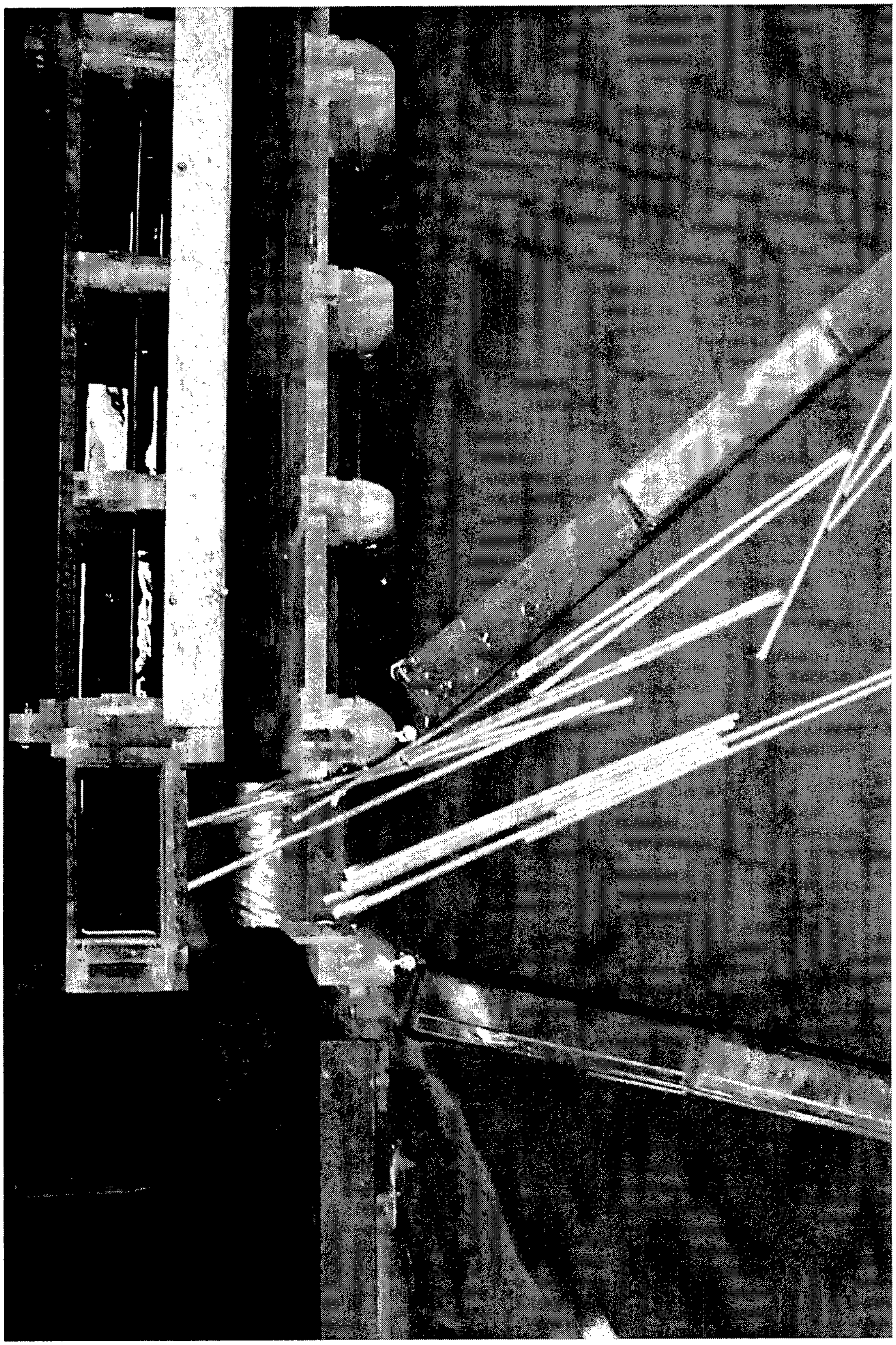


Photo 23. 60-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 71.5

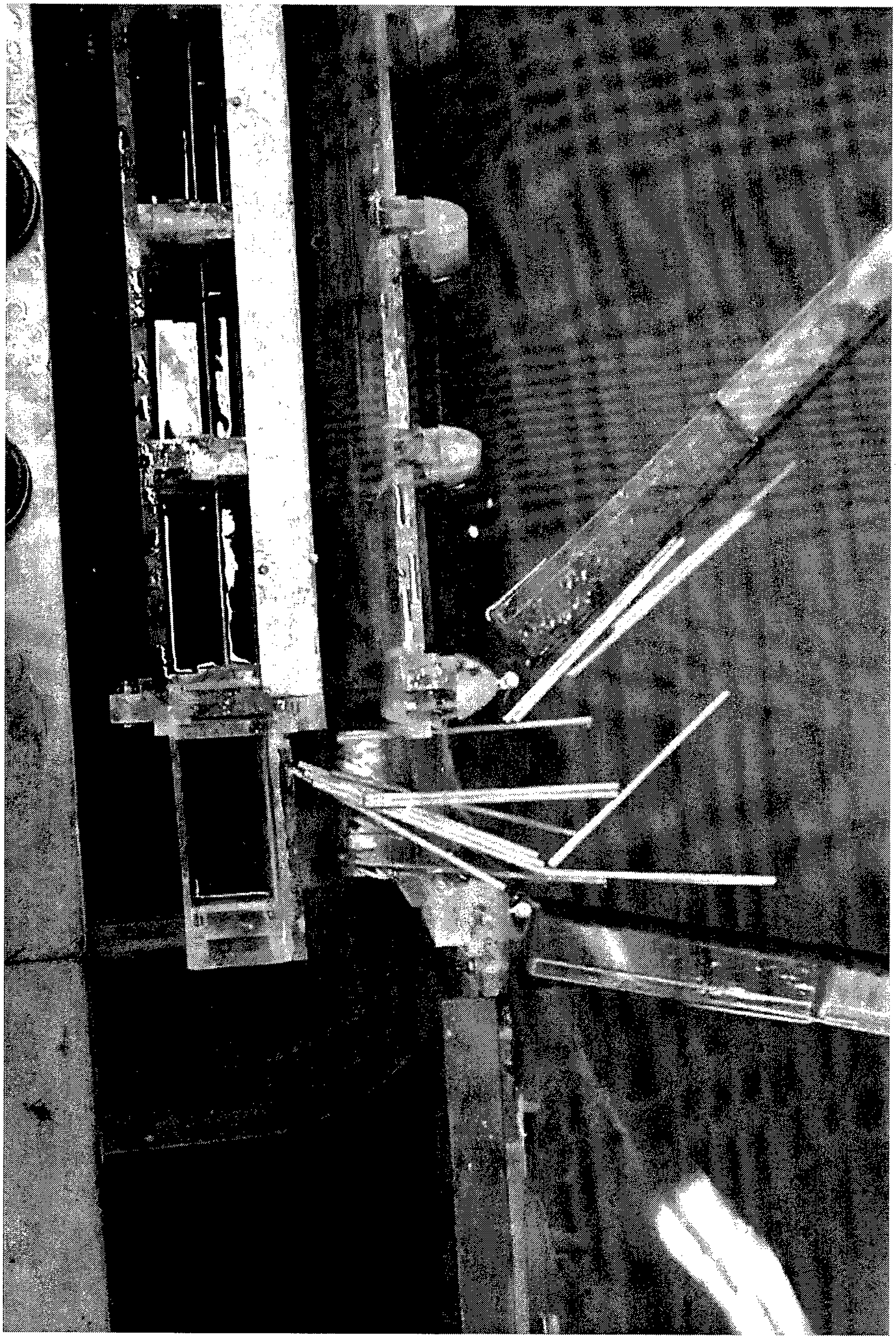


Photo 24. 33-ft dowels at Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 71.5

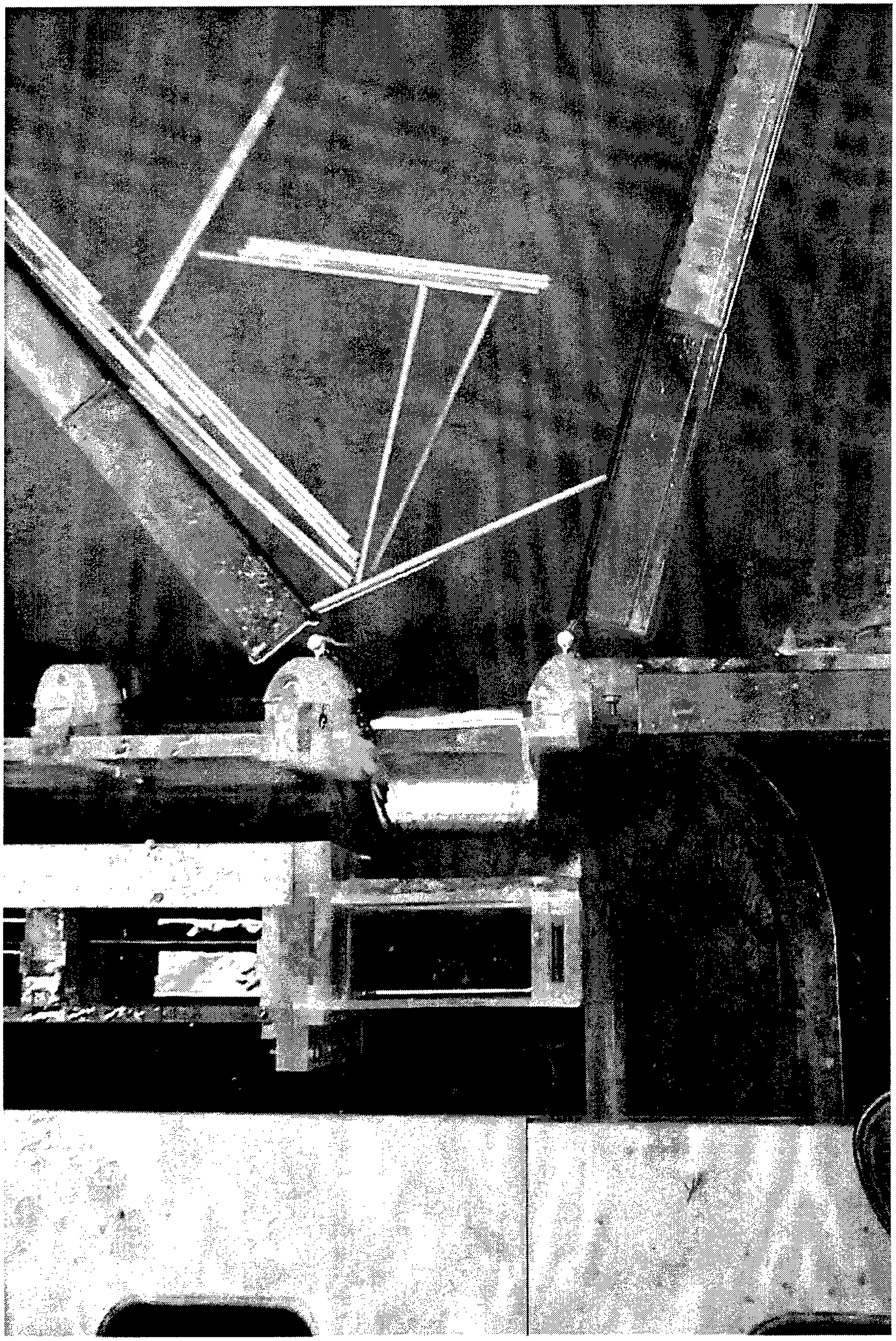


Photo 25. Dowels blocking Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 71.5

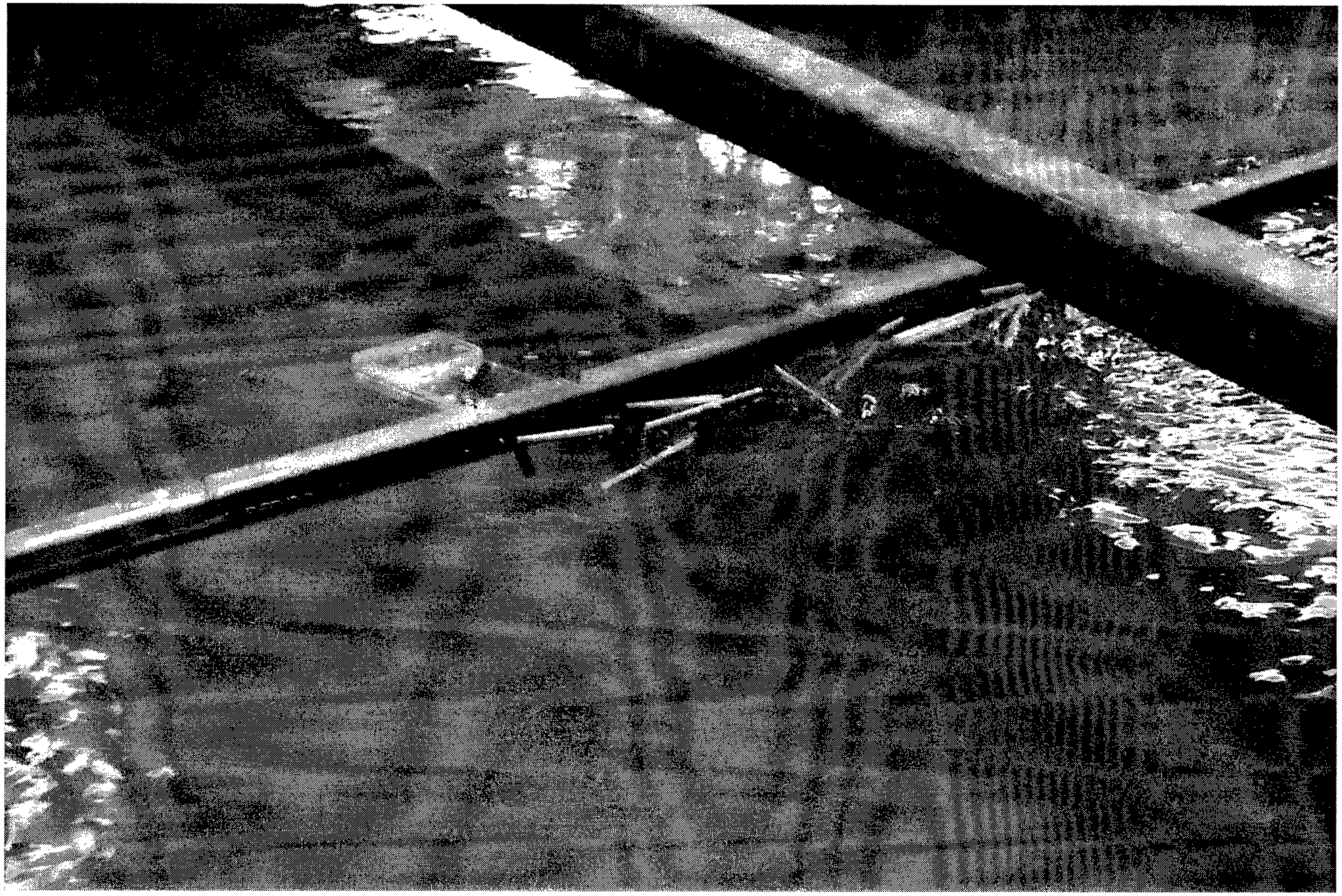


Photo 26. Various debris moving along trash boom; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 71.5

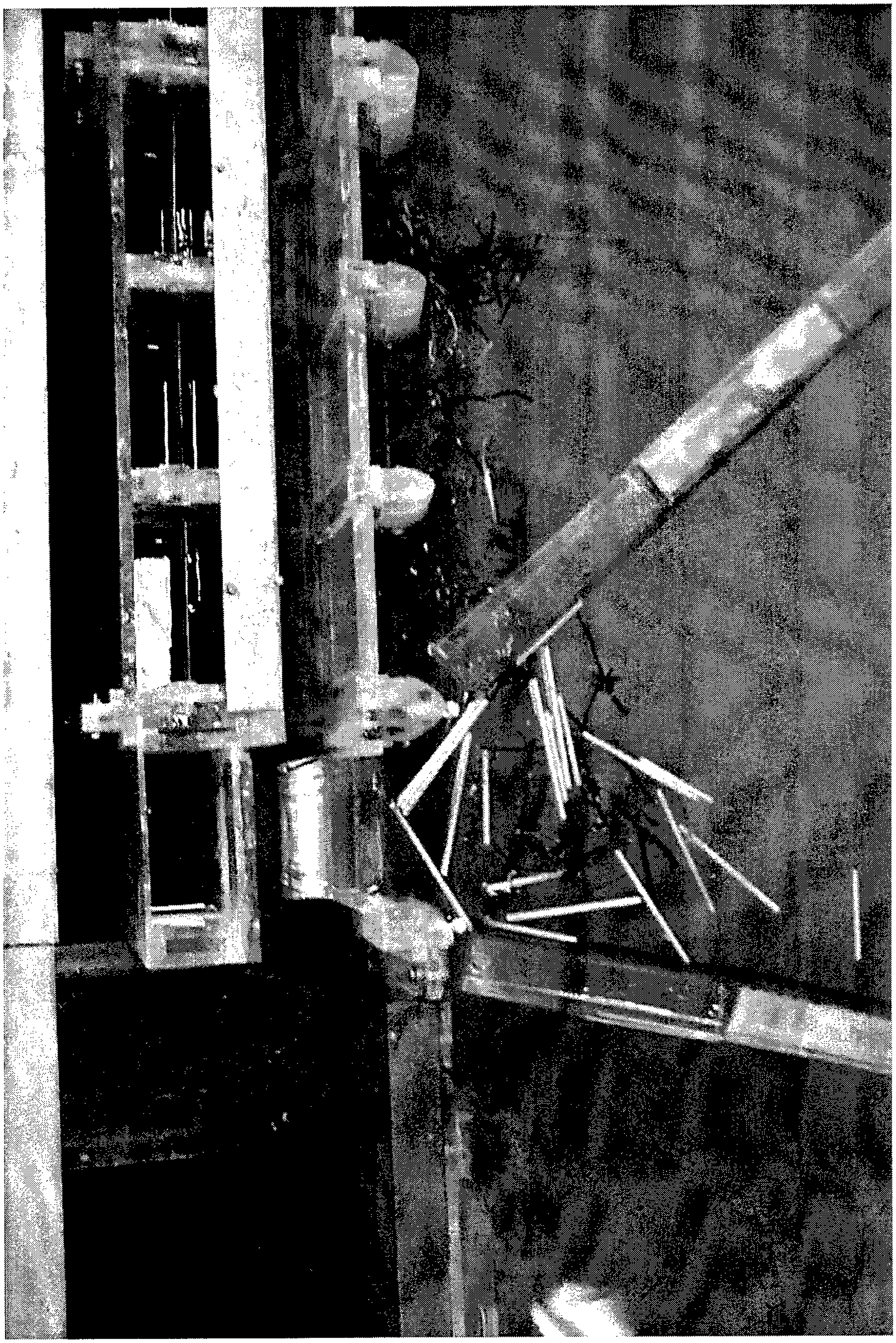


Photo 27. Debris at powerhouse Unit 1 and in Unit 0 sluiceway entrance; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 71.5

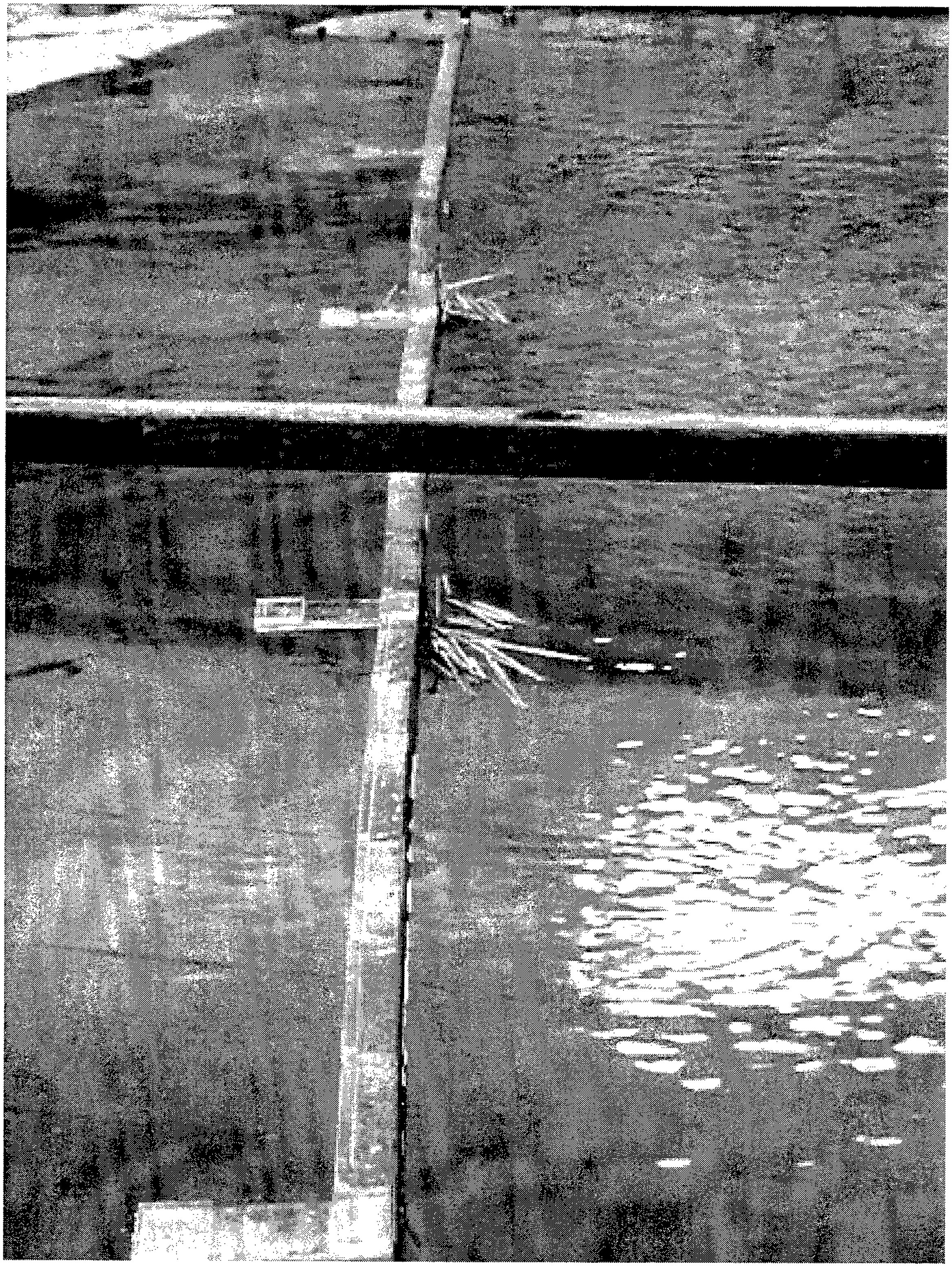


Photo 28. 8-ft anchor extension experiments; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

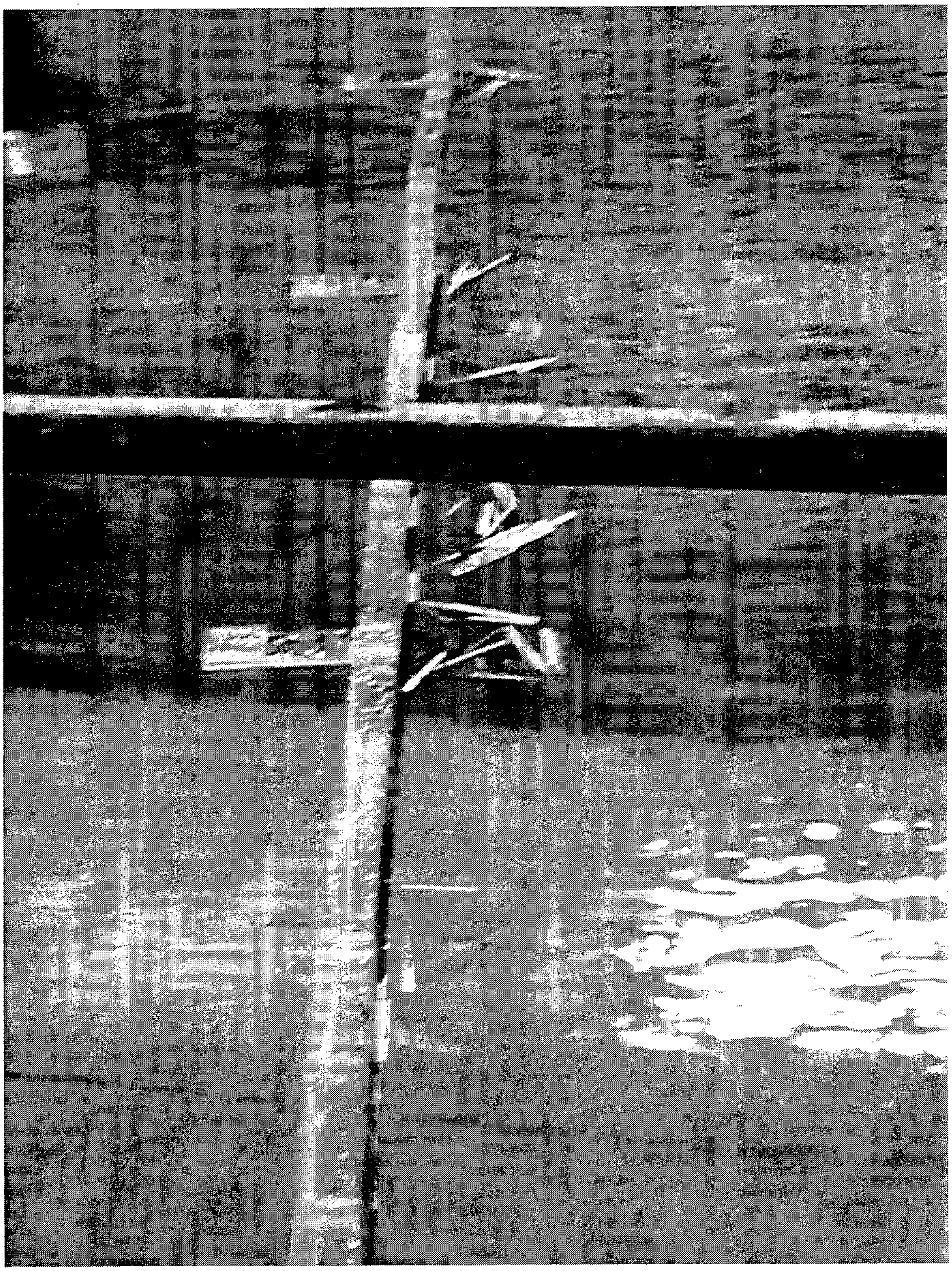


Photo 29. 8-ft anchor extension experiments; original boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

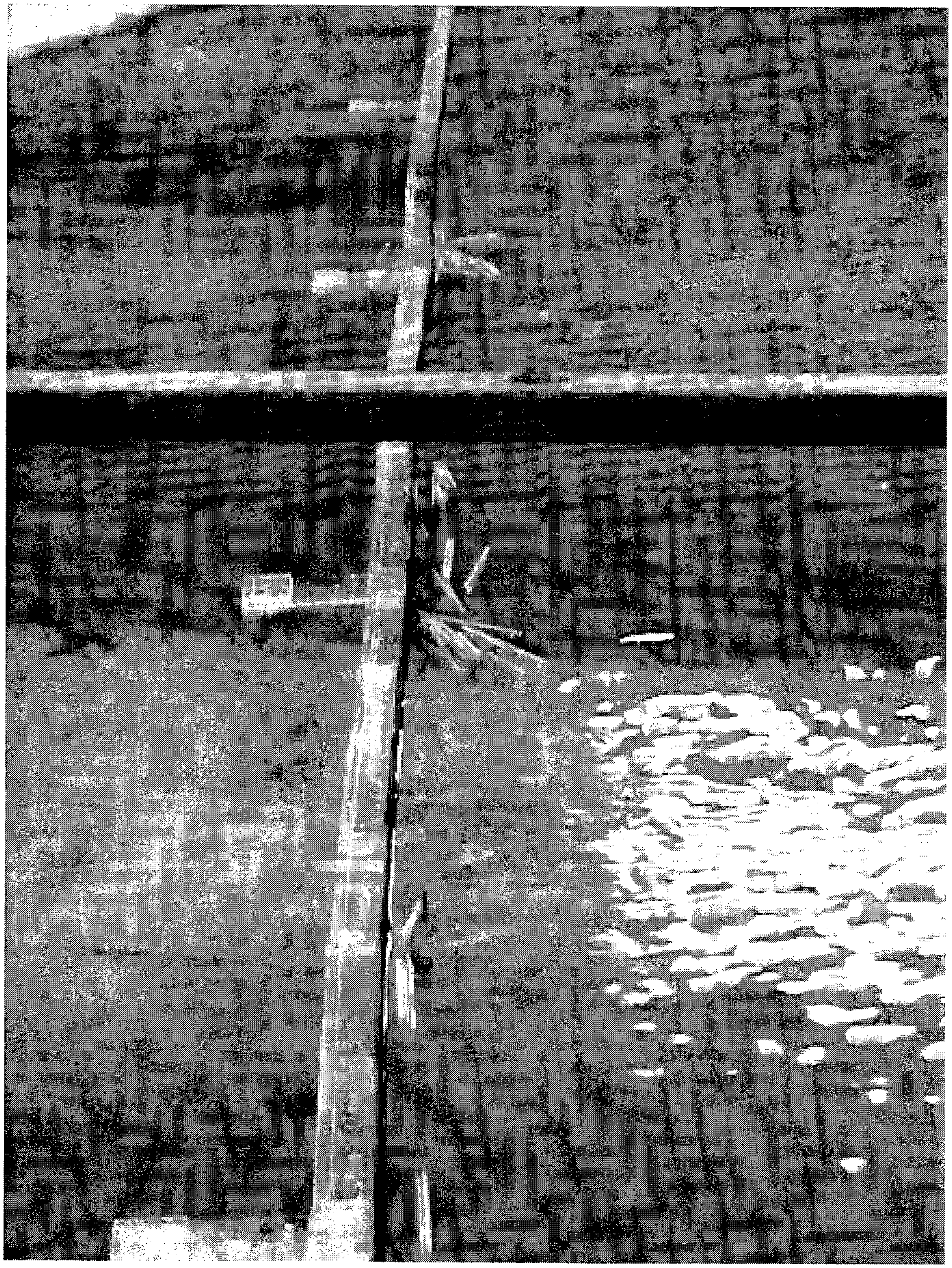


Photo 30. 8-ft anchor extension experiments; original boom alignment; discharge per unit 382.293 cu m/sec (13,500 cfs); pool el 74.5

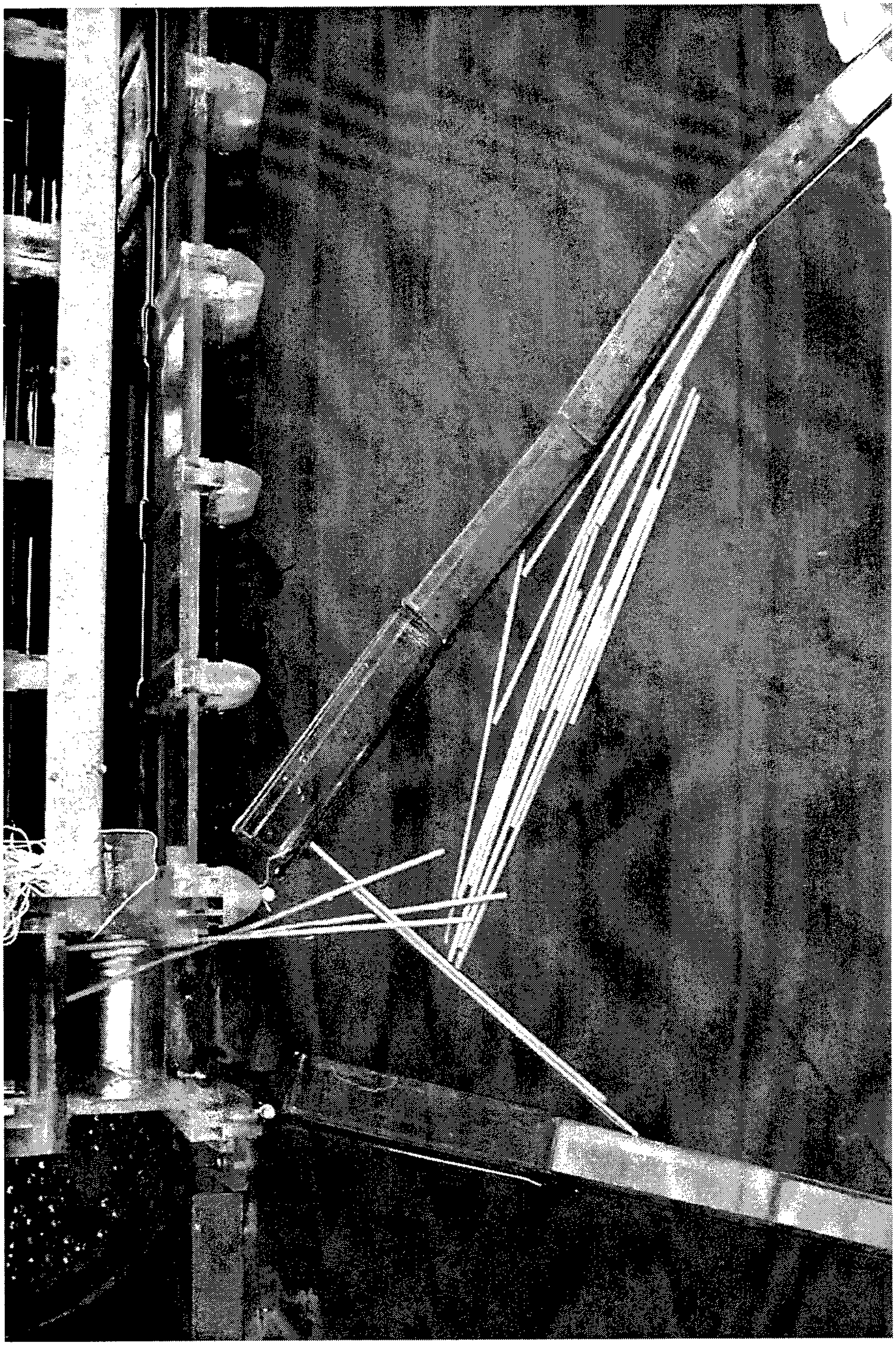


Photo 31. 60-ft dowels at Unit 0 sluiceway entrance; final boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

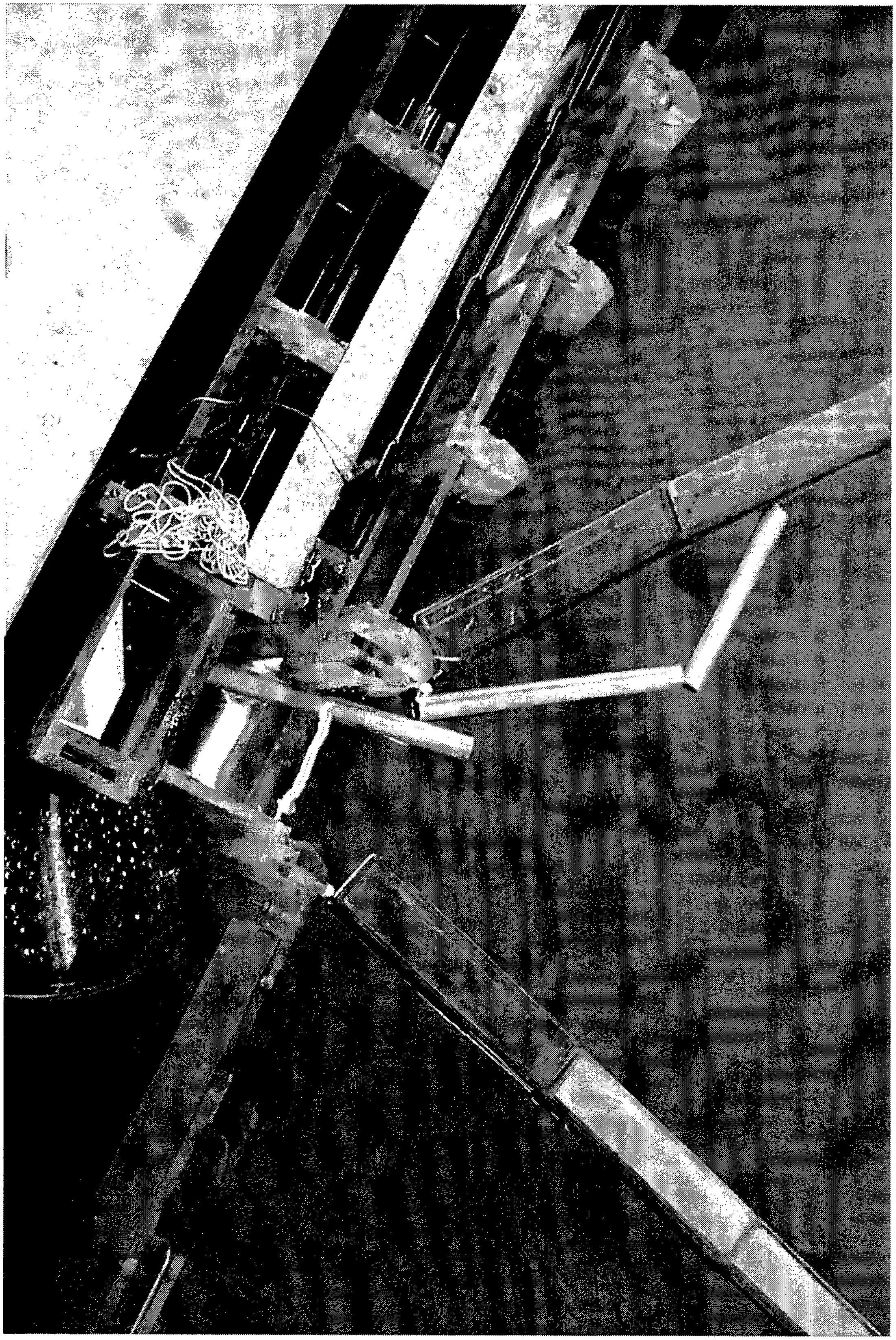


Photo 32. 3.5-ft diameter debris experiment; final boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

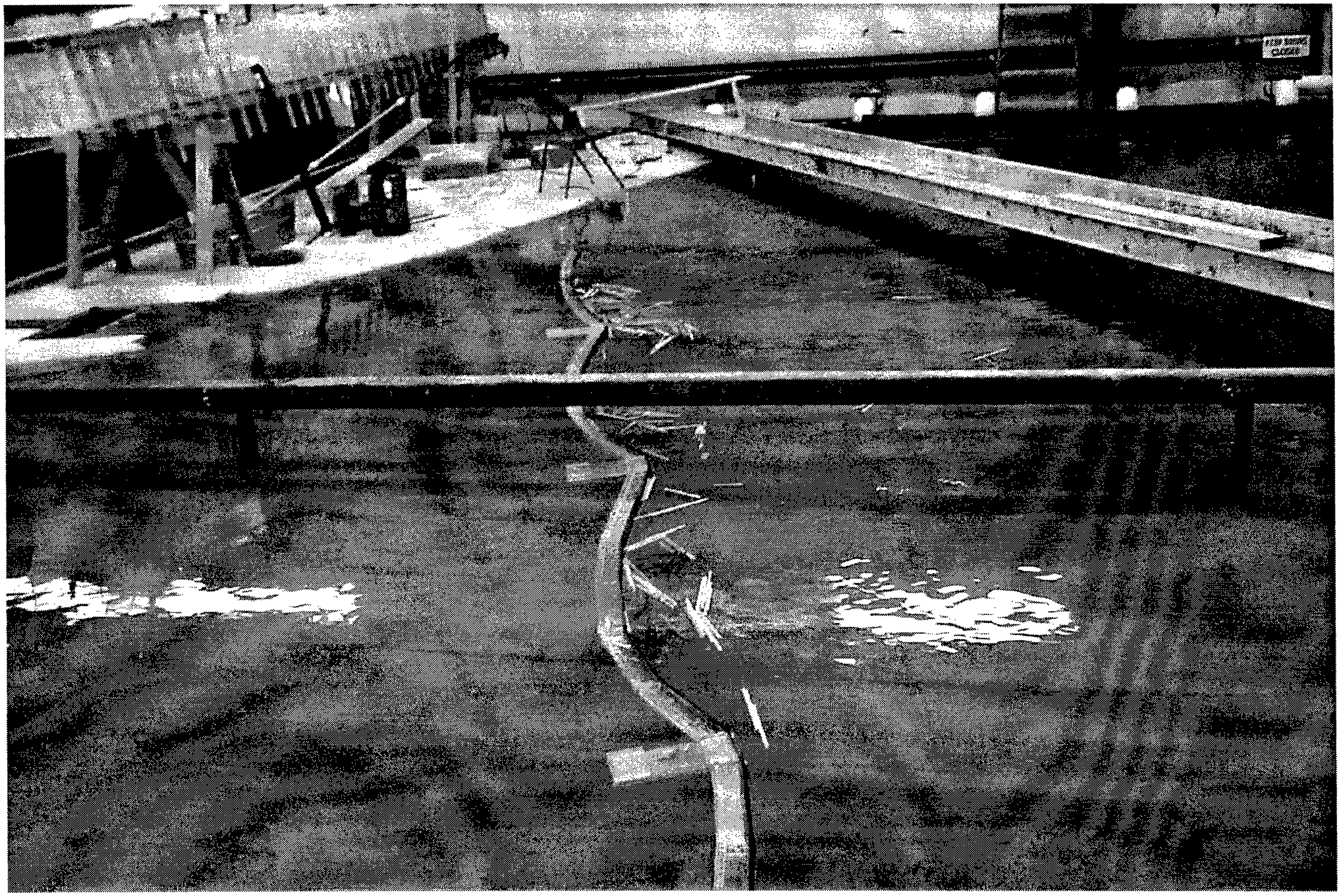


Photo 33. Debris collecting along the trash boom; final boom alignment; discharge per unit 297.339 cu m/ sec (10,500 cfs); pool el 74.5

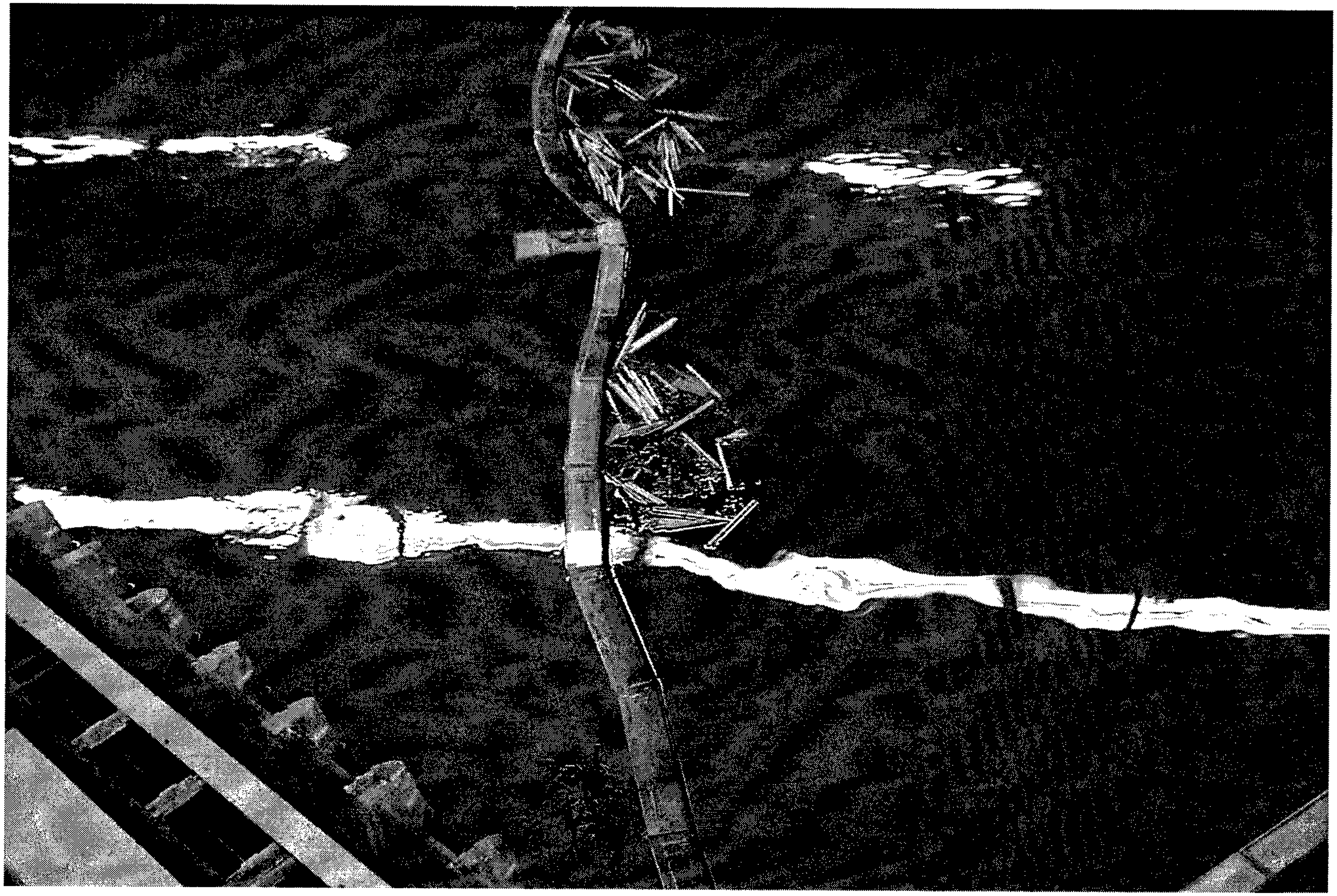
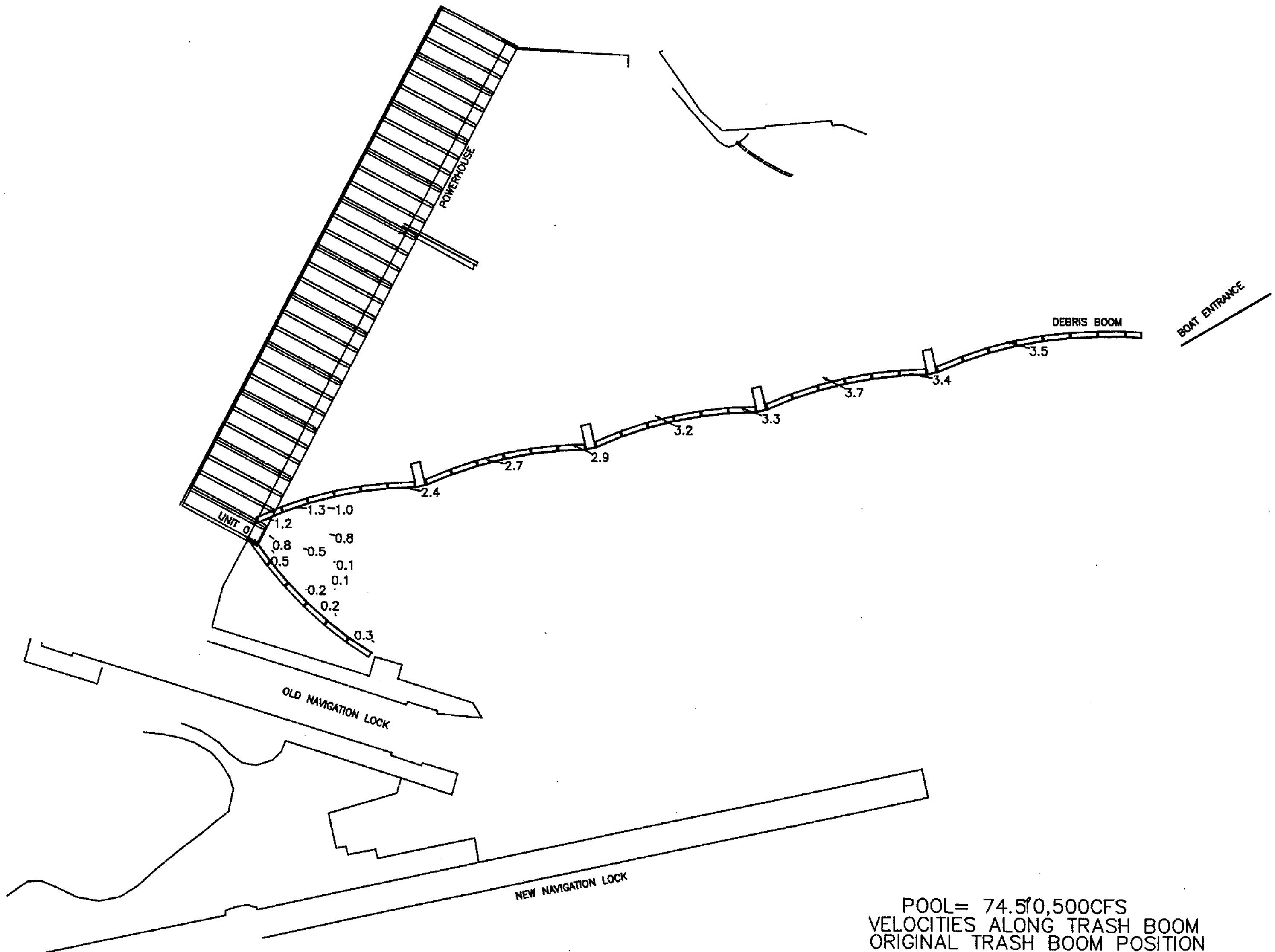


Photo 34. Debris collecting along the trash boom; final boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5

Photo 35. Debris at powerhouse Unit 1 and in Unit 0 sluiceway entrance; final boom alignment; discharge per unit 297.339 cu m/sec (10,500 cfs); pool el 74.5



POOL= 74.5⁄10,500CFS
VELOCITIES ALONG TRASH BOOM
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN AT WATER SURFACE

PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND (To convert to meters per second multiply by 0.3048)

Plate 1

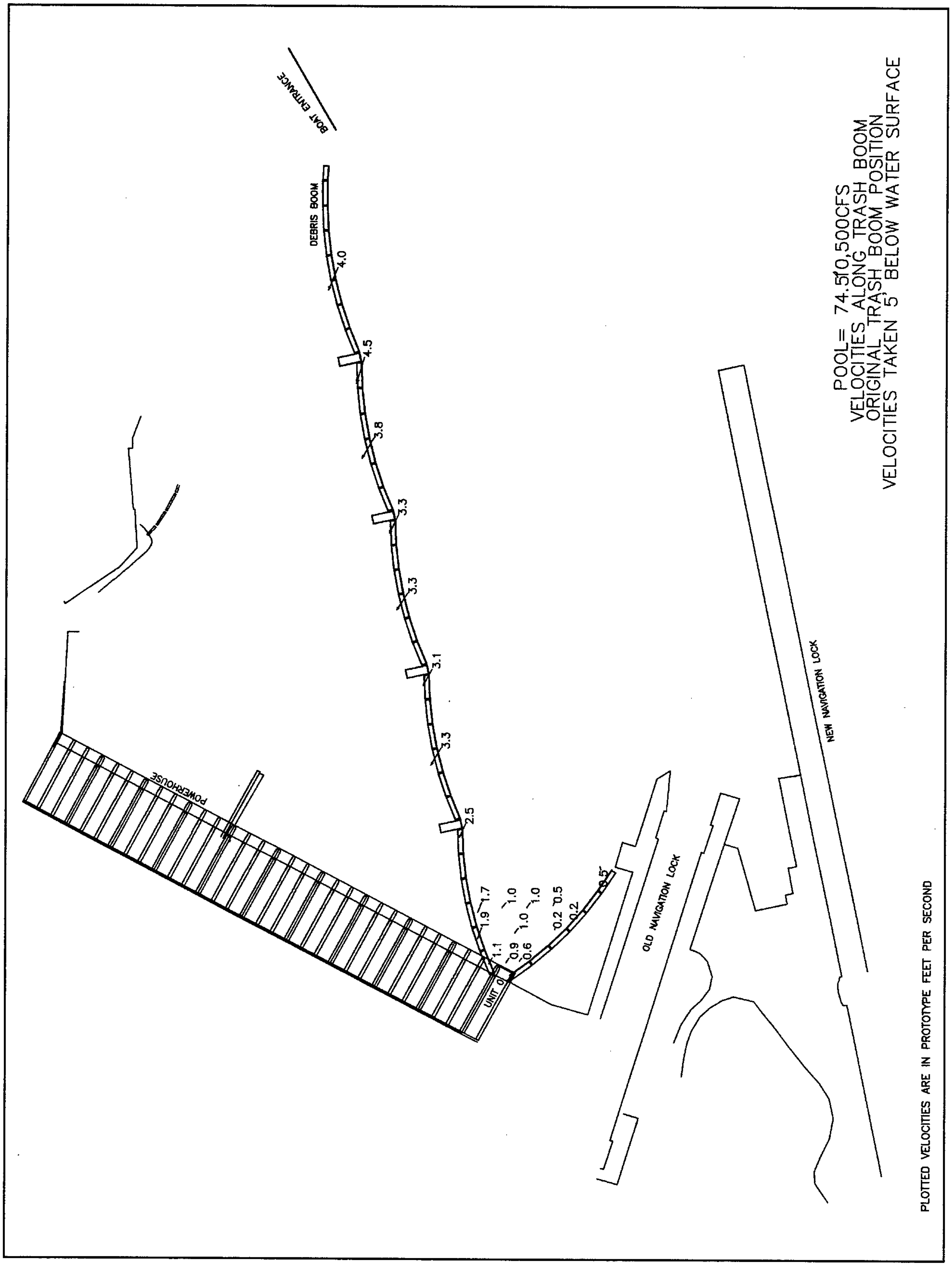
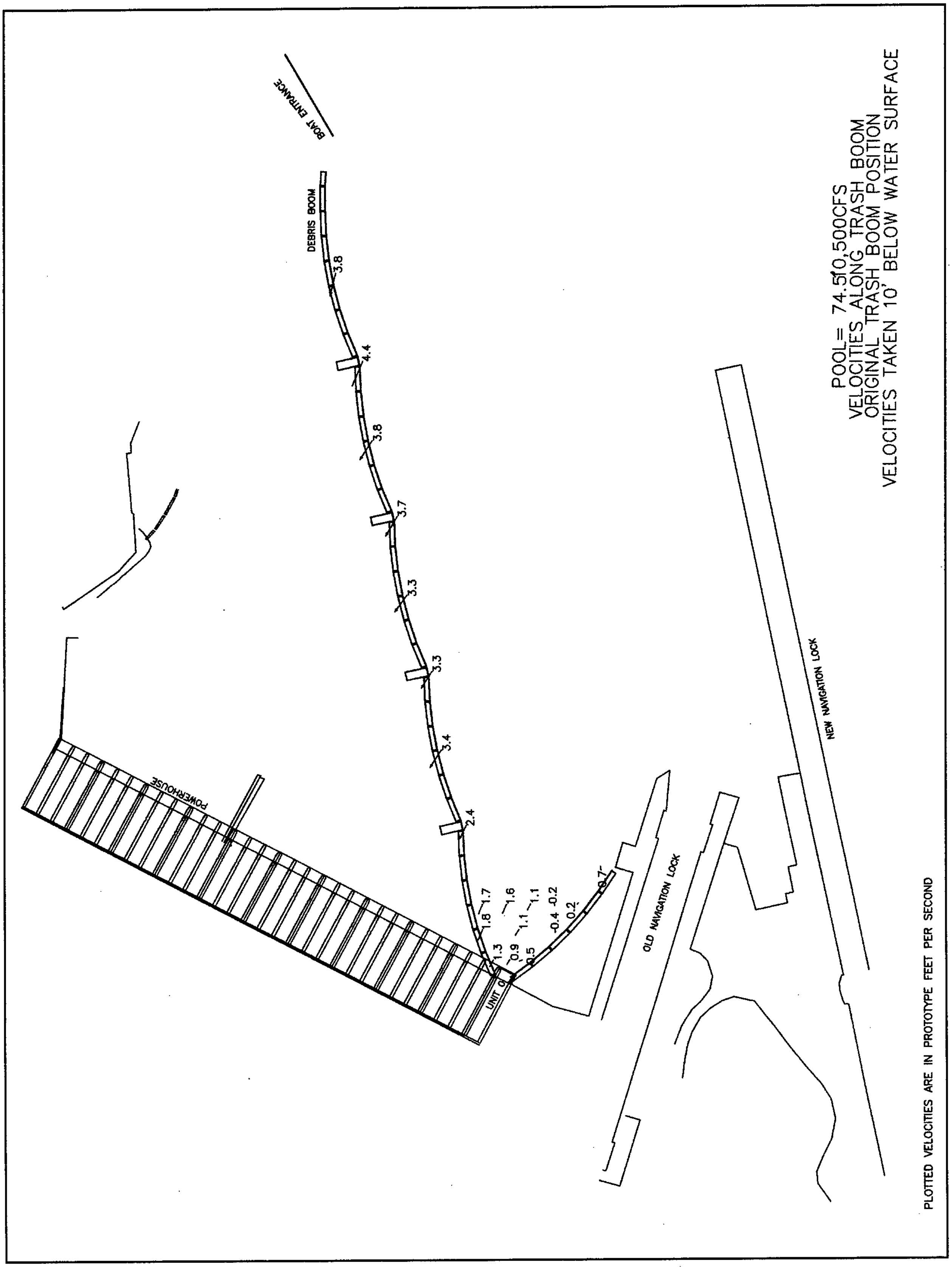
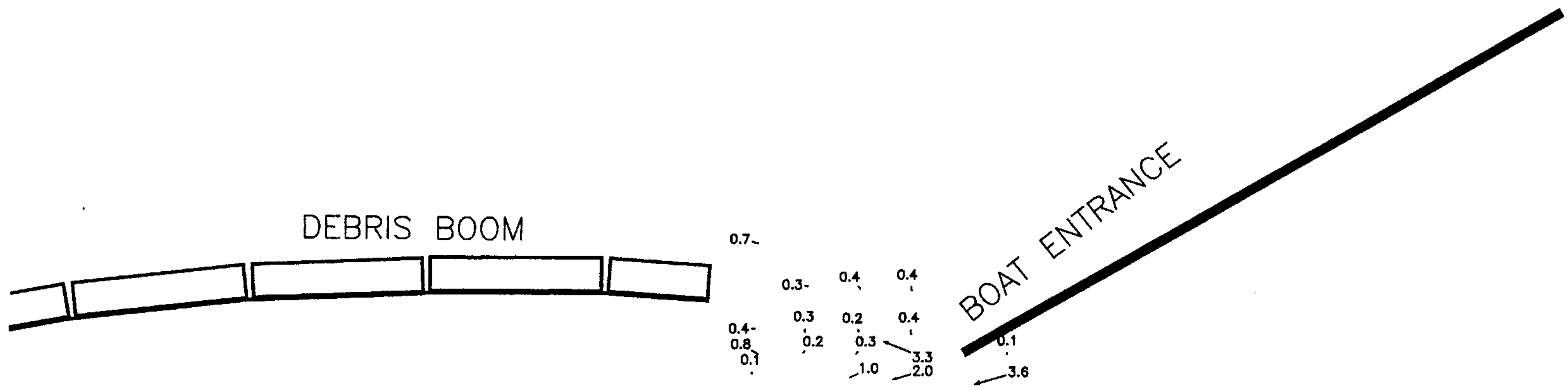

POOL= 74.5, 10,500CFS
VELOCITIES ALONG TRASH BOOM
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN 5' BELOW WATER SURFACE
BOAT ENTRANCE
DEBRIS BOOM
POWERHOUSE
UNIT 0
OLD NAVIGATION LOCK
NEW NAVIGATION LOCK
4.0
4.5
3.8
3.3
3.3
3.1
3.3
2.5
1.9
1.7
1.1
1.0
0.9
1.0
0.6
1.0
0.2
0.5
0.2
0.5
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

Plate 2



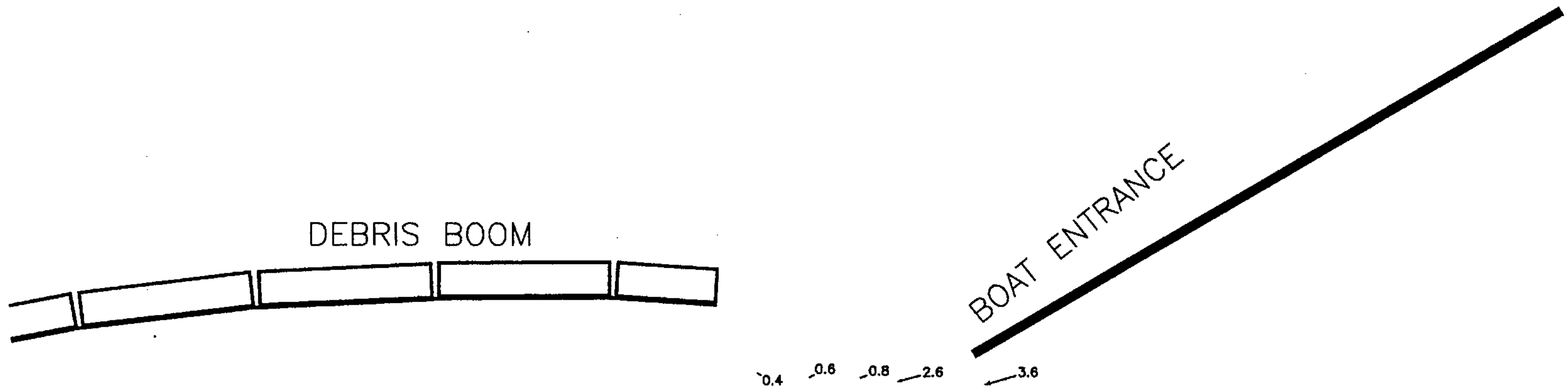
POOL= 74.5 10,500CFS
VELOCITIES ALONG TRASH BOOM
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN 10' BELOW WATER SURFACE
BOAT ENTRANCE
DEBRIS BOOM
3.8
4.4
3.8
3.7
3.3
3.3
3.4
2.4
1.8
1.7
1.6
1.1
1.1
1.3
0.9
0.5
-0.4
-0.2
0.2
0.7
POWERHOUSE
UNIT 0
OLD NAVIGATION LOCK
NEW NAVIGATION LOCK
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND



POOL = 74.5 FT   Q = 10,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN NEAR TOP OF WATER COLUMN

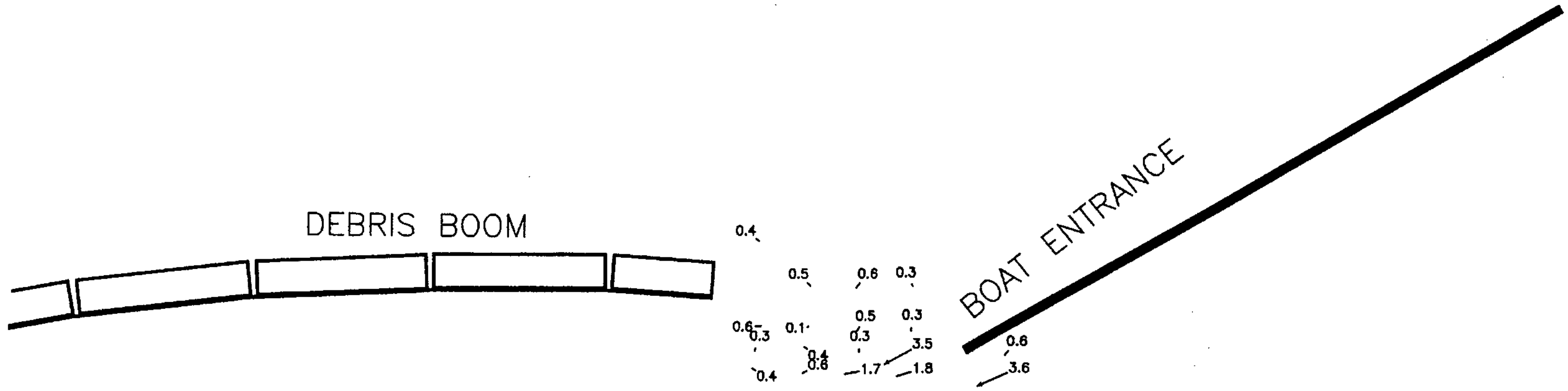
VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND

Plate 4



POOL = 74.5 FT   Q = 10,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN AT MIDDLE DEPTH

VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND



POOL = 74.5 FT. Q = 10,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN AT BOTTOM DEPTH

VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND

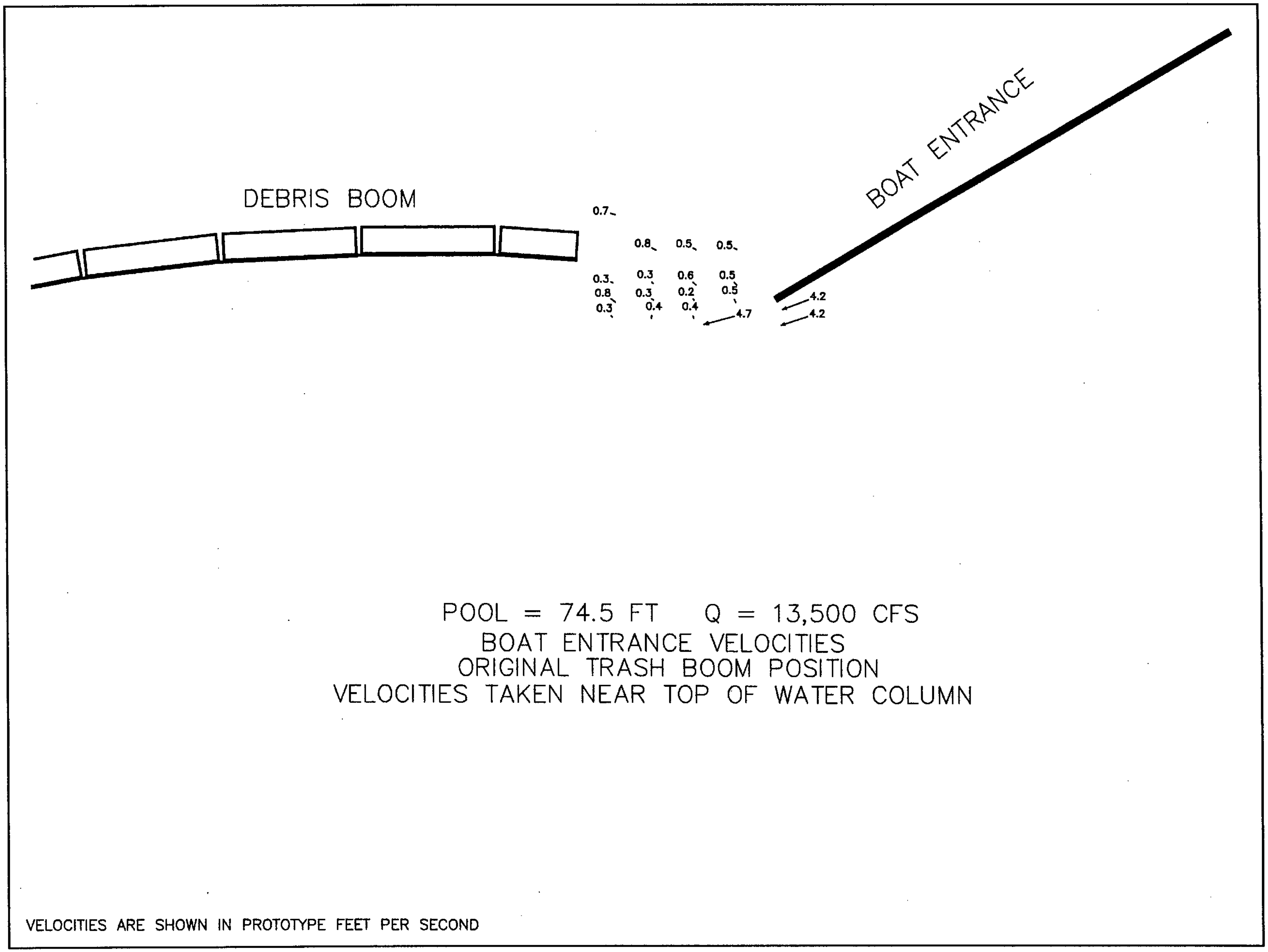

DEBRIS BOOM
BOAT ENTRANCE
0.7
0.8
0.5
0.5
0.3
0.8
0.3
0.3
0.3
0.4
0.6
0.2
0.4
0.5
0.5
4.7
4.2
4.2
POOL = 74.5 FT Q = 13,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN NEAR TOP OF WATER COLUMN
VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND

Plate 7

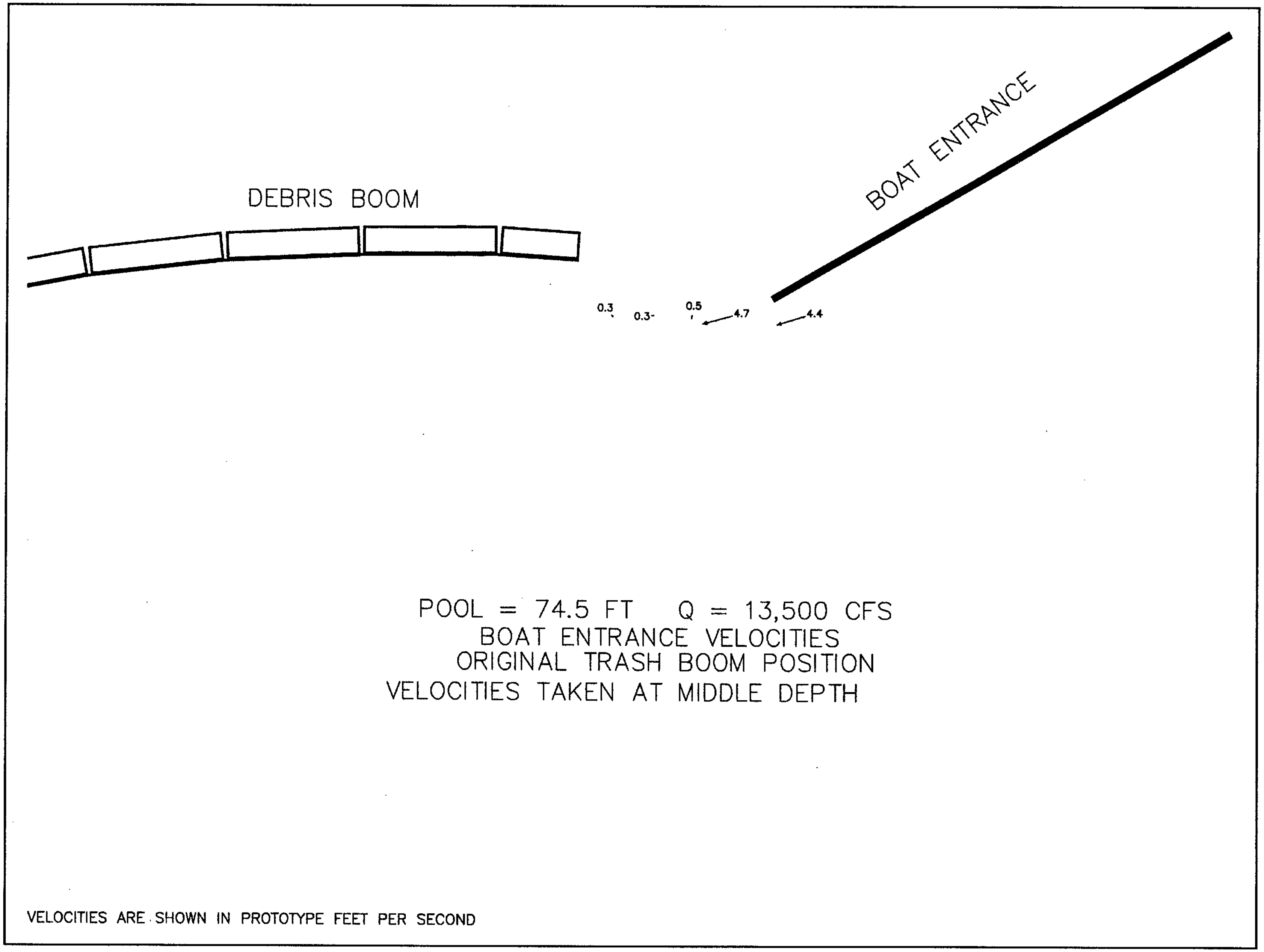
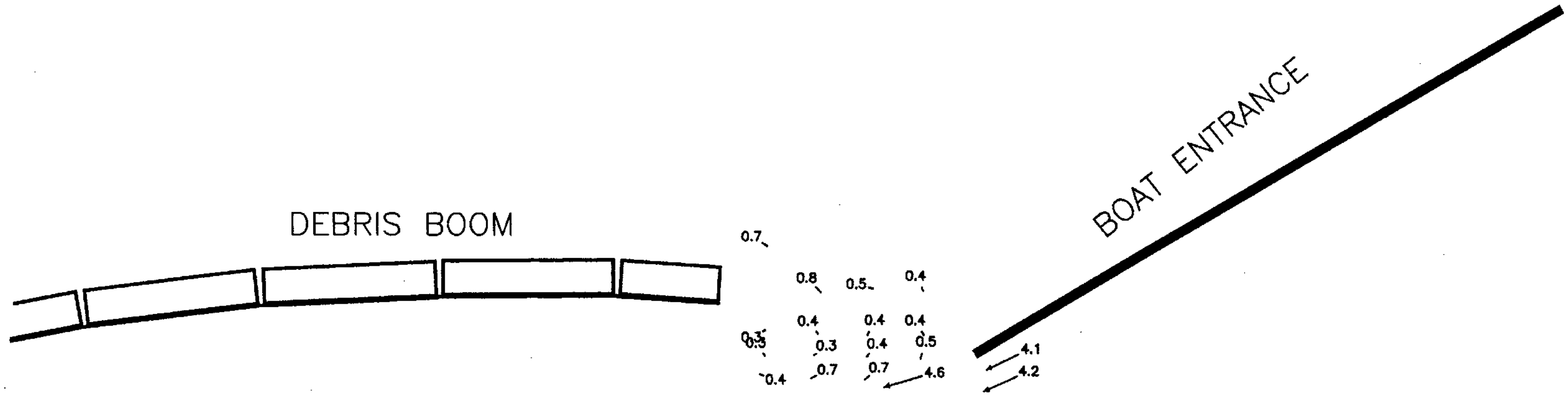

DEBRIS BOOM
BOAT ENTRANCE
0.3
0.3
0.5
4.7
4.4
POOL = 74.5 FT Q = 13,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN AT MIDDLE DEPTH
VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND

Plate 8



POOL = 74.5 FT Q = 13,500 CFS
BOAT ENTRANCE VELOCITIES
ORIGINAL TRASH BOOM POSITION
VELOCITIES TAKEN AT BOTTOM DEPTH

VELOCITIES ARE SHOWN IN PROTOTYPE FEET PER SECOND

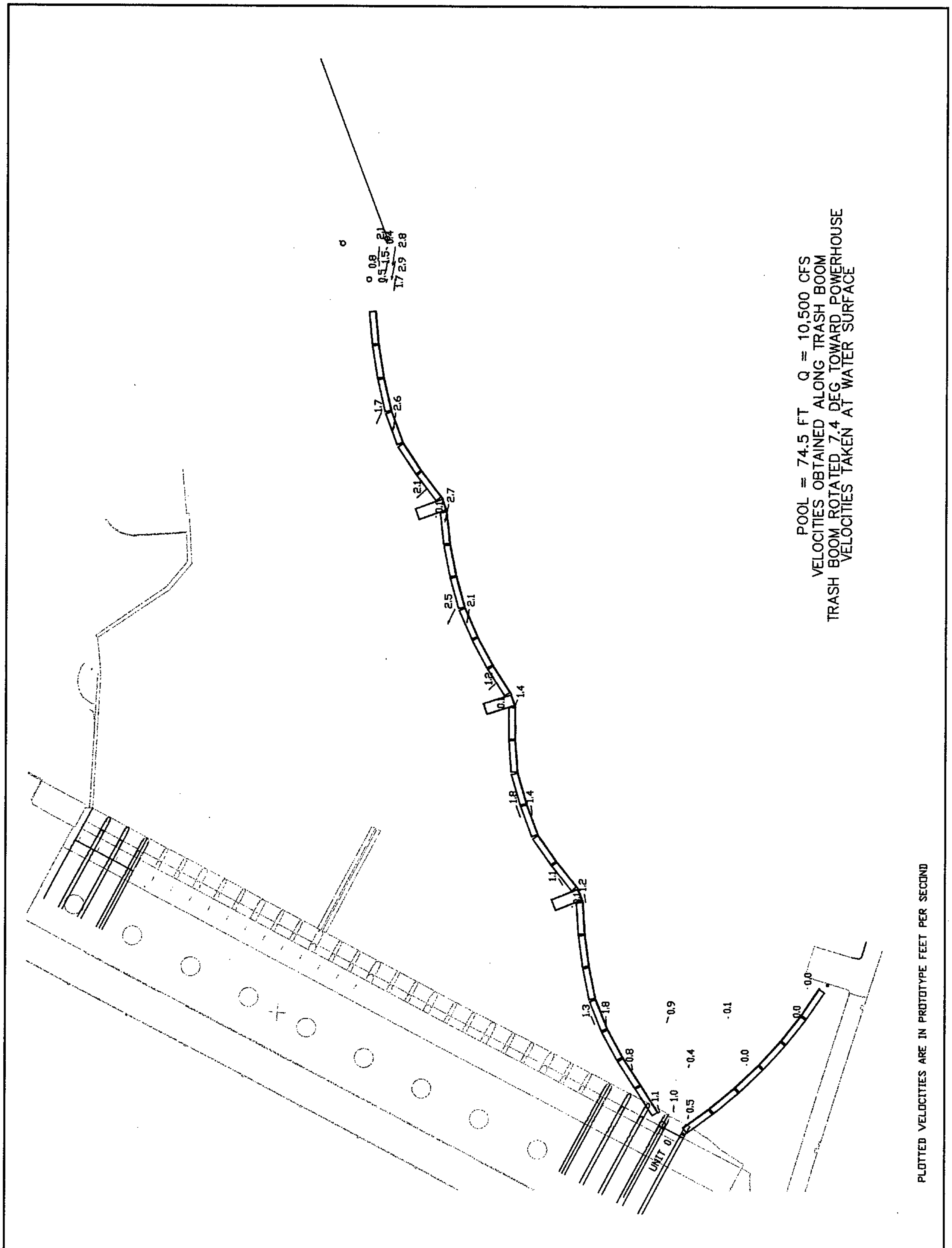

POOL = 74.5 FT Q = 10,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN AT WATER SURFACE
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND
UNIT 01

Plate 10

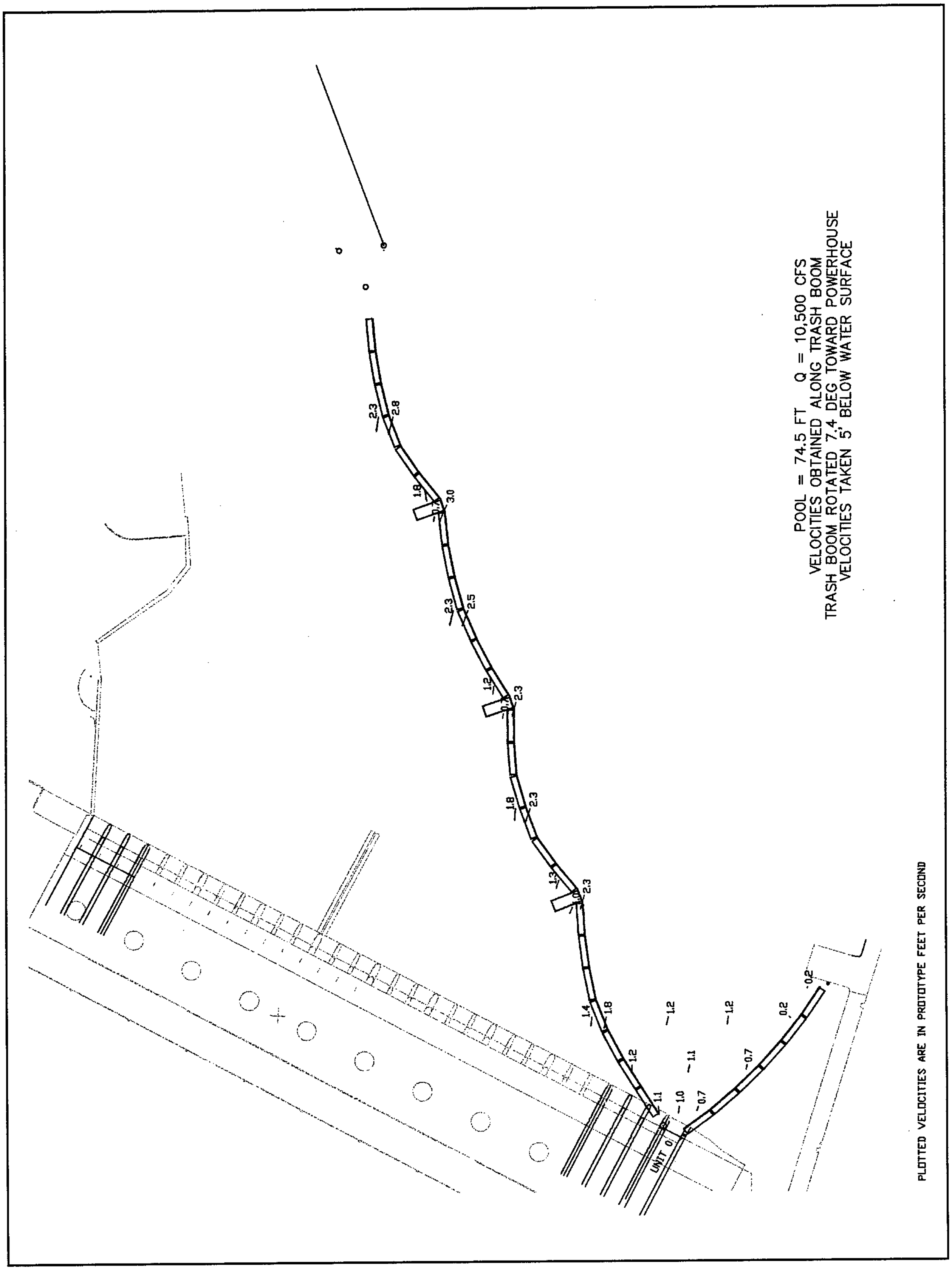
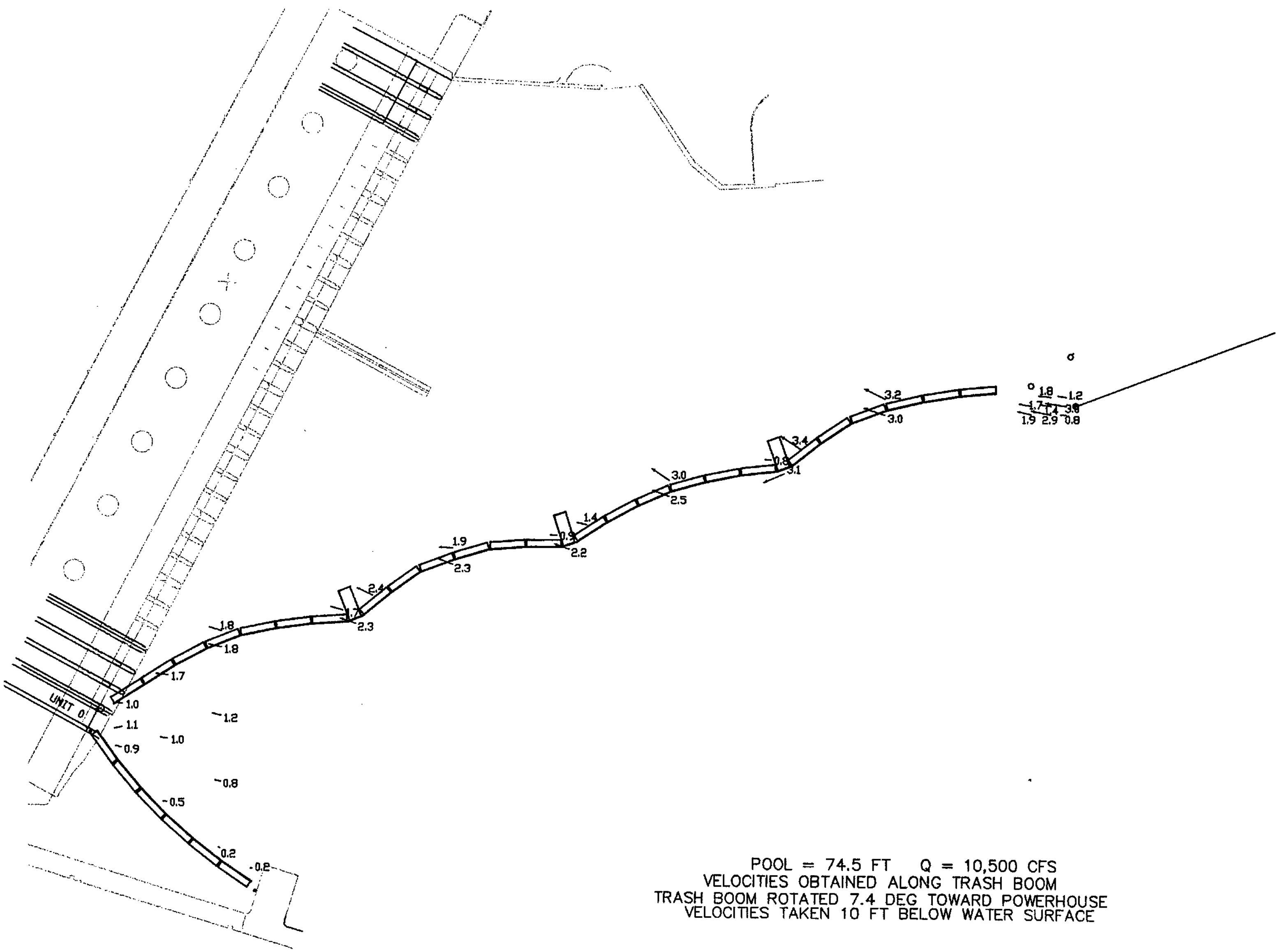

POOL = 74.5 FT Q = 10,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN 5' BELOW WATER SURFACE
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

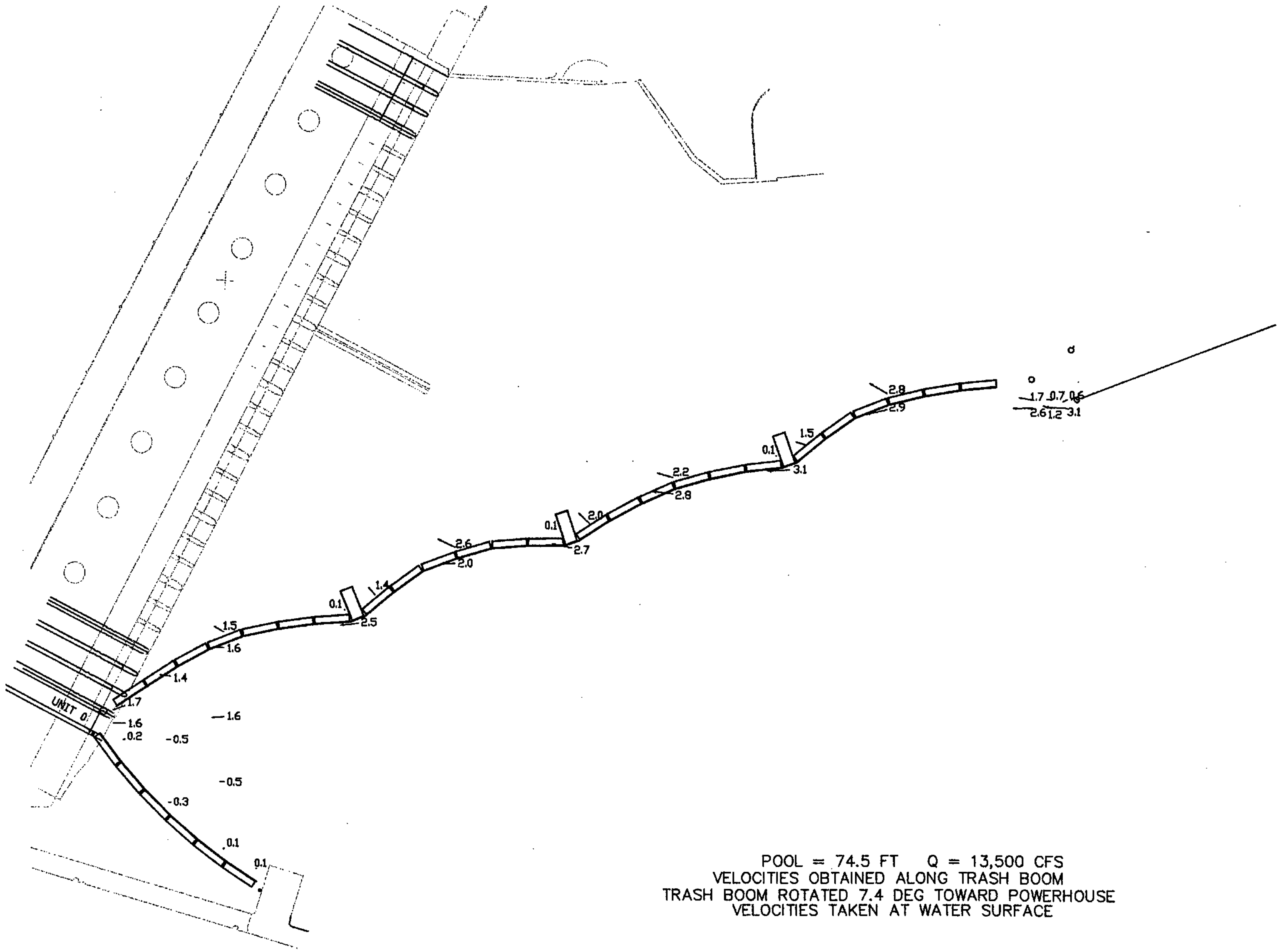
Plate 11

Plate 12



POOL = 74.5 FT Q = 10,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN 10 FT BELOW WATER SURFACE

PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND



POOL = 74.5 FT Q = 13,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN AT WATER SURFACE

PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

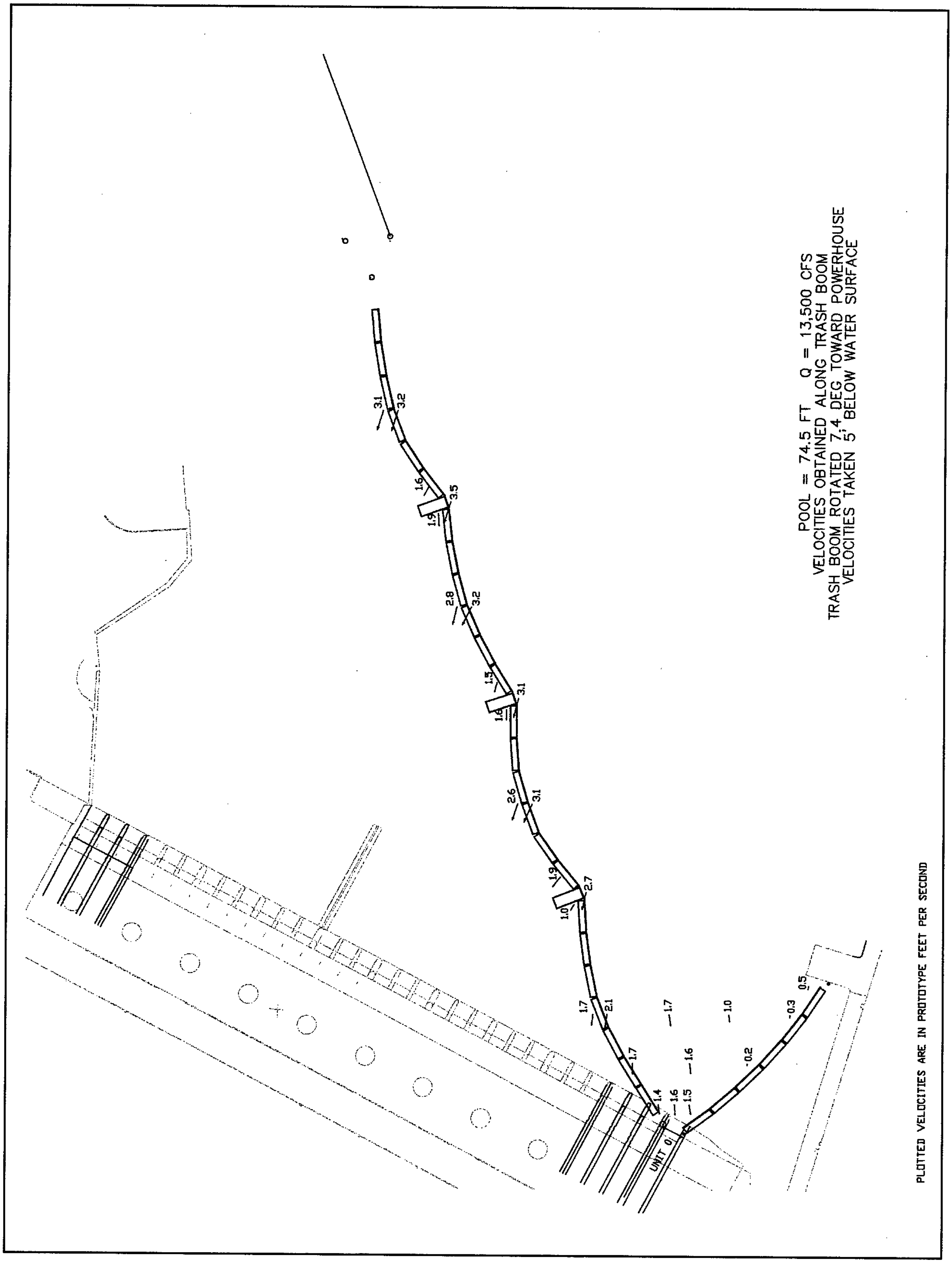
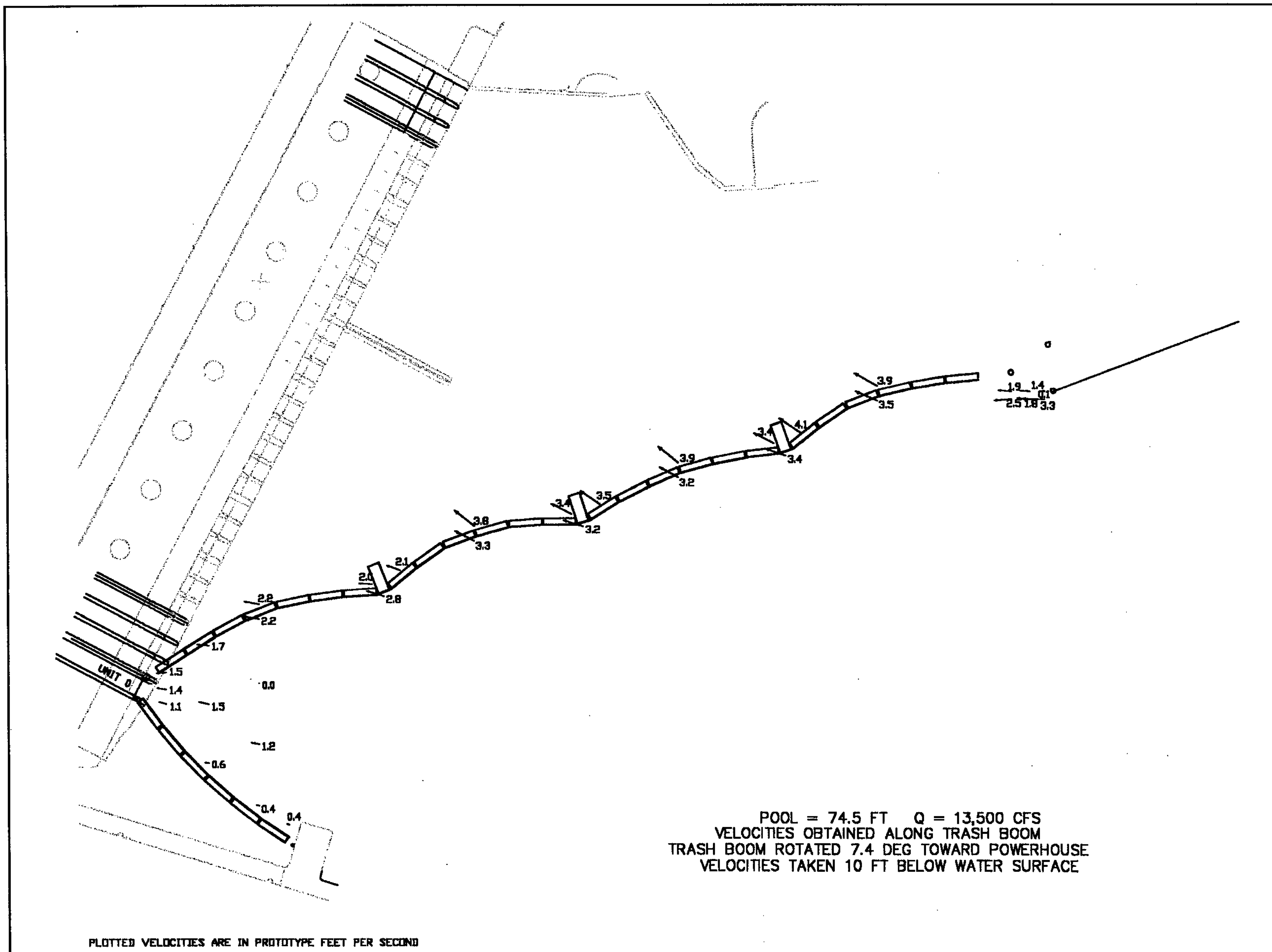

POOL = 74.5 FT Q = 13,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN 5' BELOW WATER SURFACE
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND
UNIT 01

Plate 14


POOL = 74.5 FT Q = 13,500 CFS
VELOCITIES OBTAINED ALONG TRASH BOOM
TRASH BOOM ROTATED 7.4 DEG TOWARD POWERHOUSE
VELOCITIES TAKEN 10 FT BELOW WATER SURFACE
UNIT 0
PLOTTED VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

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14. ABSTRACT

Potential changes to juvenile bypass system would significantly reduce the flow capacity of the existing ice and trash sluiceway, resulting in the sluiceway not being able to pass trash and ice from the forebay to the tailrace efficiently. Utilizing a 1:40-scale model of the Bonneville First Powerhouse, various possible trash boom location scenarios were evaluated. The trash boom would be used to collect and direct ice and trash to the Unit 0 sluiceway opening efficiency. The investigation involved velocity measurements along the trash boom to assist in determining the hydraulic loading, and several different types of floating debris were used to evaluate the effectiveness of various trash boom designs.

15. SUBJECT TERMS
Floating debris, Ice and trash sluiceway, Powerhouse, Trash boom

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